Sustainable agriculture and nature values

- using Vejle County as a study area

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Anna Bodil Hald
Department of Landscape Ecology
Department of Policy Analysis

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Author: Anna Bodil Hald
Department: Department of Landscape Ecology / Department of Policy Analysis

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Abstract: The size of protected natural areas is small and is an always decreasing figure - and so is the botanical quality of natural areas. Contemporary agriculture does not *a priory* integrate the necessary extensive management of nature values. Therefore, maintaining the nature values of the agricultural landscape has to be taken into consideration as an integrated part of sustainable agriculture. This report, using Vejle County as a study area, analyses the influence from farm and soil type on five main variables affecting nature values: (i) area of farm and land use; (ii) grazing potential within rotation and outside rotation; (iii) use of pesticides and nutrients; (iv) location of farm type in relation to grazing dependent semi-natural areas and potential areas for permanent grasslands on low-lying land; (v) location of a farm type with high ammonium emission in relation to oligo-/mesotrophic areas sensitive to additional nutrient loads.

The results show that different farm types potentially support or impact nature values of terrestrial natural areas to a different degree. The rank of farm types in relation to expected nature values is part-time > small cattle > large cattle, small plant, large plant, small pig > large pig with part-time farms having the greatest potential to support nature values.

Keywords: Farm type; Geographical location; Grazing potential; Land use; Low-lying land; Semi-natural areas; Small biotopes.

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National Environmental Research Institute
Grenåvej 12, Kalø
DK-8410 Rønde
Tel.: +45 89 20 17 00
Fax: +45 89 20 15 14

Miljøbutikken
Information and Books
Læderstræde 1
DK-1201 Copenhagen K
Tel.: +45 33 37 92 92
Fax: +45 33 92 76 90

Contents

"Naturen er til at juble over i kraft af dens skønhed og storslåethed. Jublen retter sig mod dens skaber, som har gjort naturen til livsgrundlag for alt levende. Mennesket er den mest magtfulde skabning; vi udnytter naturen til at skabe en særlig virkelighed i naturen: Civilisation og kultur.

Men vi er ikke hævet over naturen; vi er fælles med alt levende om at være forgængelige. Og vi har et ansvar, netop fordi vi er så magtfulde: Vi ved, hvilke konsekvenser vores indgreb har for den øvrige natur. Vi kan ikke være mennesker, uden at det sker på andre levende væseners bekostning.

Men vi kan pålægge os selv begrænsninger, så naturudnyttelsen ikke bliver overflødig naturødelæggelse."

Svend Andersen "Hvilken salig jubel ...", Samvirke 9, 1997.

Preface

This report has been prepared under the Danish Ministry of Agriculture's research programme "Agricultural Production Under Changing Social and Environmental Conditions (1993/1997), within Part 1b of the project "Sustainable Strategies for Agriculture". The aim of Part 1b "Ecological and Immaterial System Variables" is to describe the impact of agricultural production on the quality of ecosystems, to quantify relationships between environment and agricultural production within different farming systems. Furthermore, to investigate scenarios of policy regulation to promote sustainability in Danish agriculture, i.e. in this case to reduce the negative impact of agriculture on the environment and nature values. The County of Vejle has been chosen as the study area for the project.

The main focus of Part 1b is on: (i) leaching of nitrogen to aquatic systems from agricultural land (Skop & Schou 1996a); (ii) calculations of the economic net output from the different farming systems and environmental consequences of policy regulation of the consumption of fertilizer through a per-unit tax on nitrogen (Schou & Skop 1997). The aim of this report is to describe the impact of agricultural production on terrestrial ecosystems and to discuss regulation required to improve quantity and quality of biotopes in the agricultural landscape as an integrated part of sustainable agriculture. Some of the data used in this report has been prepared in co-operation with Jesper S. Schou (Danish Institute of Agricultural and Fisheries Economics) and Eli Skop (National Environmental Research Institute).

Developments in the field of landscape ecology have created a need for new terminology, or at least, more precise definition of terms used. The use of the word 'habitat' in the English language is considered rather too general for this report, since the 'habitat' of animals often includes more than one biotope, whereas the habitat of plants includes only one biotope. As this report mostly concerns the relationships between agriculture and the vegetation, the term 'biotope' is used and is defined in Appendix 3. Certain other terms have now become established in the Danish language and an explanation and definition of their translation to English and usage is given in Appendix 3.

Dansk resumé

Kun en meget lille del af Danmarks areal er autentisk natur, beskyttet af Naturbeskyttelsesloven - og så bliver dette areal tilmed stadig mindre på grund af lovens mulighed for at dispensere til at ændre eller nedlægge områder. Dertil kommer, at kvaliteten af de tilbageværende arealer er under stadig forringelse. I modsætning til tidligere integrerer moderne landbrug ikke *a priori* den nødvendige ekstensive drift af natur-værdierne på disse arealer. Hvis man vil bevare natur-værdierne i agerlandskabet, er det derfor nødvendigt at inddrage denne opgave som en integreret del af bæredygtigt landbrug.

Nærværende rapport, der anvender Vejle Amt som værkstedsområde, analyserer indflydelsen fra bedrifts- og jordtype på fem hovedvariable, der forventes at influere på natur- ærdierne: (i) bedriftens arealmæssige størrelse og arealanvendelse; (ii) græsningspotentiale inden for og uden for rotationsarealerne; (iii) anvendelsen af bekæmpelsesmidler og gødning; (iv) den geografiske placering af bedriften i forhold til græsningsafhængig natur i halv-kulturarealer som ferskeng, strandeng og overdrev og i forhold til arealer, der er potentielle som permanent græsningsarealer på lavbund; (v) den geografiske placering af bedrifter med høj ammonium udslip i forhold til næringsfattige naturtyper, der er følsomme over for øget belastning med næringsstoffer.

Resultaterne viser, at potentielt gavner eller skader de forskellige bedriftstyper den terrestriske natur meget forskelligt. En rangordning af bedriftstyperne i forhold til størrelsen af deres forventede naturværdier er deltidsbrug > små kvægbrug > store kvægbrug, små plantebrug, små svinebrug > store svinebrug, hvor deltidsbrug udviser det største potentiale for at understøtte naturen.

Hvis samfundet ønsker at opnå et højere indhold af natur i agerlandskabet, er det nødvendigt at sætte naturen som direkte mål for de politiske indgreb. En analyse af effekten på naturen af en 100%'s enhedsafgift på kvælstof i både kunstgødning og foder viser således, at en sådan afgift kun har ringe effekt på de terrestriske natur-værdier. En afgift sikrer hverken øget areal til naturen eller mere plads til vilde planter og dyr på de dyrkede marker. Ej heller sikrer en afgift, at permanent græsning af halv-kulturarealer opretholdes. I nærværende rapport konstateres det, at krav om een eller anden form for basis natur på bedriftsniveau er den eneste måde, hvormed naturen kan sikres generelt i agerlandskabet. De minimumsbud, der gives i rapporten på størrelsen af en sådan basis natur i bæredygtigt landbrug bygger på princippet om, at natur-værdierne skal understøttes ens af alle bedriftstyper og være lige så gode på alle bedrifter som på den bedste inde for hver af de fem hovedvariable. Dertil kommer, at nogle landmænd på grund af en speciel geografisk placering, bedriftens historie eller på grund af særlig interesse fra landmandens side har specielle muligheder for at bidrage med natur-værdier ud over basis naturen. Det foreslås i rapporten, at samfundet yder disse landmænd særlig bonus-points.

1 Introduction

The interactions between agriculture and semi-natural areas are two-way. The introduction of agriculture in Denmark has, over a period of several hundred years, changed the land use from wet virgin forests kept more or less open by the grazing of wild ungulates and boar to a grassland landscape grazed by domesticated animals. By about 1800, few forest areas were left in the landscape (2% of the area, Anonymous 1994) which was grazed by cattle and sheep, and grasslands made up the matrix in which cultivated fields surrounded the settlements. The majority of valuable, open terrestrial types of natural areas in Denmark today are the remnants of these areas grazed by domestic animals and which in general have not been suitable for cultivation with available techniques, or where cultivation ceased again after a few years. These remaining areas are called semi-natural. The wild plant species of the vegetation of these semi-natural areas have for a long time benefited from extensive (i.e. without fertilizers and pesticides, but often with small open drainage ditches in wet areas) agricultural management, such as hay-cutting and grazing of wet and dry meadows, or undergone special management (for example heathland). Some Danish natural areas - such as small biotopes - have been created by farmers, for example marl pits, field lanes, most hedgerows, and stone fences and earth walls between fields as well as between fields and forests. Furthermore, small biotopes such as those linear biotopes along fields with grazing animals were influenced to various degrees. For example, cattle grazed the edge along the outside of electric fences if the fence consists of only one strand, and formerly it was common to graze the verges along smaller roads by tethered calves. Thus, the former broad occurrence of semi-natural areas and establishment of small biotopes ultimately resulted from farmers activity.

Management of heathland, however, is not integrated in agricultural production any longer, and contemporary agriculture has often ploughed and cultivated semi-natural grasslands or at least intensified the management of these areas. However, maintenance of the species rich vegetation in semi-natural areas is completely dependent on management by extensive hay-cutting and/or grazing (Persson 1984; Bakker 1989). Intensified management involves the application of fertilizers and pesticides, drainage, sowing of culture grasses and high grazing pressure. Other areas of semi-natural grasslands have been abandoned and, no longer receiving management, have entered secondary succession ultimately leading to forests. Thus contemporary agriculture does not *a priori* integrate the extensive management necessary to maintain valuable semi-natural areas. Therefore, maintaining the biotope quality[1] of these areas has to be taken into consi-

[1] In this report, biotope quality is defined as the botanical departure from an expected, or ideal, biotope under a specific set of abiotic conditions and management as a measure of quality (Mogensen et al. 1997b). As this term is under more specific definition for terrestrial types of natural areas in an ongoing project at the National Environmental Research Institute (Mogensen et al. 1997b), the less specific term "nature value" is mostly used in this report.

deration as an integrated aspect of sustainable agriculture in the future.

Different types of semi-natural areas most often occur as small and isolated fragments in the contemporary Danish agricultural landscape and thus less mobile species might have difficulty in dispersing from one locality to another. Therefore, the natural process of maintaining biodiversity through immigration of species that have disappeared from an area has often been disrupted. Although fields in rotation have a more or less continuous distribution and the cultivated field is the most common biotope type in the landscape, the biodiversity of wild plants of arable areas has decreased dramatically (Andreasen et al. 1996). The reasons are manifold, but most important is increased crop yield through the combined effects of increased use of fertilizers and pesticides together with growing high yielding crop varieties, and change in land use. The goal, high yields of agricultural fields, will probably continue to be the goal in the future, therefore, maintaining the nature values of fields in rotation has to be taken into consideration as an integrated aspect of sustainable agriculture in the future.

Based on information in the literature, this report describes the landscape, soil and types of natural areas of the study area (Vejle County) and observed changes in agriculture from the 1950's to the 1990's of influencing variables that are expected to be important for nature values (Chapters 2 and 3). The relationships between influencing agricultural variables, and the impact on nature values are referred from the literature (Chapter 4). Interactions between defined farm types and different types of biotope and the effect on different biotope types of present-day location of the different farm types are analysed (Chapters 5 and 6). Finally, the effect on nature values of a 100% tax on nitrogen is evaluated, and restrictions on farming practice that must be included in an 'Action Plan for Sustainable Agriculture' if nature values (biodiversity) are targeted and the aim is to fulfil the Rio Convention on Biodiversity[2], are discussed (Chapter 7).

The farm types used in this report have been defined by the Danish Institute of Agricultural and Fisheries Economics according to line of production, soil type, and economic size (Schou, Skop & Hald 1995). The interactions between agriculture and nature values focus on three main farm type variables: (i) land use including farm size and type of crop; (ii) animal husbandry including grazing potential and ammonia pollution; (iii) yield level including consumption of fertilizers and pesticides. Also, the geographical location of the farms in relation to biotope types is referred to. Concerning nature values, this report focuses on: (i) vegetation; (ii) terrestrial biotope types; (iii) biotope types traditionally managed by farmers or created by farmers and types of natural areas protected by §3 in the 1992 Protection of Nature Act. Thus forests are not considered.

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[2] cf. Chapter 7 in Prip & Wind (1995).

2 The landscape and types of natural areas in the study area, Vejle County

Vejle County has been chosen as the study area for the project "Sustainable Strategies in Agriculture" as it was found to be representative of a Danish landscape dominated by agriculture, also in respect of soil types, land use and agricultural structure (Schou & Skop 1995). This chapter describes the landscape, soil, potential types of natural areas and existing natural areas[1], and looks at Vejle County for its representativity concerning types of natural areas. Furthermore, the types of natural areas are discussed in relation to the direct and indirect influence from agriculture.

2.1 Landscape and soil

The total area of Vejle County is about 300,000 ha, of which about 64 % is agricultural land (Table 1). Vejle County may be described by three types of 'Natural and cultural' landscapes (Jensen & Kuhlmann 1987): (I) *Det egentlige Østjylland* (pure east Jutland landscape); (II) *Overgangszonen langs Den Midtjyske Højderyg* (the transition zone along the Mid-Jutland lateral moraine); (III) *Hedeslette-Bakkeø* (heath plain and hill island), mentioned in decreasing order of area occupied by the landscape types in Vejle County.

Agriculturally the three 'Natural and cultural' landscapes are characterised by Nordic Councils of Ministers (Jensen & Kuhlmann 1987) as:

I. Cultivation of the eastern clay region has taken place over a long period and has only been restricted by topography in some areas. The area has a long tradition of plant production and grazing has primarily been restricted to the narrow river valleys and their steep valley slopes.

Table 1 Land use of classified soil in Vejle County in the 1990's. Source: Larsen & Sørensen (1996).

	Area of classified soil, Vejle County	
	ha	% of total area
Classified areas		
Agriculture	191,309	63.8
Forestry	38,043	12.7
Fresh water	2,388	0.8
Urban area	16,783	5.6
Other land use areas	51,334	17.1
Total area	299,857	100

[1] Existing natural areas are the natural areas registered according to the §3 of the 1992 Protection of Nature Act.

II. Cultivation of clay areas on upland has taken place for a long time, but cultivation and agricultural utilisation of the sandy slopes varied through time. Because of the geology, water for irrigation is difficult to extract.

III. Agriculture was originally restricted to river valleys. Cultivation of heath areas between the valleys and introduction of irrigation first through supply ditches from rivers (irrigated meadows) and later through pumping of ground water plus application of artificial fertilizers has made cultivation of annual crops possible.

The location of the three 'Natural and cultural' landscape types are identical with the area dominated by clay soils to the east, the area with a mixture of clay and sand, and the sandy soils to the west (Fig. 1, Fig. 2[2]). Precipitation follows the landscape elements, varying from 720 mm in the east to 963 mm on the sandy soil in the west (Eli Skop Pers. comm.). Sloping areas (with a slope > 6%), which are considered as more or less marginal for rotational cropping (Madsen & Holst 1987), account for 4.8% (11,405 ha) of the area of Vejle County; this is among the highest percentage among the 14 counties in Denmark (Emsholm 1987). Areas classified as 'lavbund' (low-lying land) by Madsen and Holst (1987) cover 7.0% (21,200 ha) of the area in Vejle County (Emsholm 1987). This figure is low compared to Denmark as a whole, which has 15% 'lavbund' (Emsholm 1987).

2.2 Types of natural areas

The potential types of natural areas of a specific area is defined as the steady-state types predicted from the physio-chemical environment - designated as physiotope - and the management regime practised (Harms et al. 1993). In Denmark, the physiotope concept for predicting potential types of natural areas has been further evaluated (Münier & Christensen 1996; Christensen 1997). The potential types of natural areas of Vejle County can be seen from a physiotope map (Fig. 3). The physiotope map has been constructed from digitised geographical data (soil types, quaternary geology, geomorphology, hydrosoil area (i.e. former wetland area), and hydrology). Six potential types of natural areas have been defined from a combination of moisture, natural nutrient availability, and management by grazing if not too wet. As seen from the physiotope map of Vejle County (Fig. 3) the potential types of natural areas of the 'Natural and cultural' areas were: Area I) fen and naturally eutrophic meadow in river valleys and other low-lying land areas, and commons on upland; Area II) a mixture of wet heath, fens, and oligotrophic and eutrophic meadows in low-lying lands, and heath and commons on upland; Area III) wet heath in river valleys and heath on upland.

The potential interaction between agriculture and nature values is dependent on biotope type[3]. Some of the natural areas outside the

[2] Text for Figs. 1 and 2 on page 11.

[3] In this chapter, only biotope types that are included in land use statistics are included.

Figure 1 (page 83) Soil map of Vejle County (Larsen & Sørensen 1996) overlaid by a soil type classification of each municipality in relation to the soil type occupying $\geq$ 80% of the municipality area: sand (fine sand and clayed sand), clay (sandy clay, clay, heavy clay or silt), and mixed (a mixture of sand and clay). S: sand, C: clay. Other municipalities are classified as having mixed soil. Inset: the area of Figs 2, 3 and 4.

Figure 2 (page 85) Section of Vejle County showing the quaternary geology. *Flyvesand*: eolian sand; *Postgl. fersk*v. *ler*: post-glacial freshwater clay; *Saltvandssand/grus*: salt-water sand/gravel; *Saltvandsler*: salt-water clay; *Morænesand*: sandy/gravelly till; *Moræneler*: clayey till; *Smeltevandssand/grus*: melt-water sand/gravel; *Smeltevandsler*: melt-water clay; *Flodslettesand/grus*: river sand/gravel; *Flodsletteler*: river clay; *Sand*: sand; *Ler*: clay; *Tørv*: peat; *Gyttje*: gyttja; *Øvrige jordarter*: Other soil types; *Sø*: lake; *Hav*: sea; *Byområde*: urban area; *Ukendt*: unknown. Source: GEUS.

Figure 3 (page 87) Section of Vejle County showing six physiotopes classified as *oligotrophic* (permanently wet, moist ~ temporary wet, and dry) and **eutrophic** (permanently wet, moist ~ temporary wet, and dry) types. The corresponding natural and semi-natural biotope types are *wet heath* (hedemose), *oligotrophic meadow* (eng), and *heath* (hede); **fen** (mose), **eutrophic meadow** (eng), and **dry grassland** (commons) (overdrev). The physiotopes have been derived from digitised data of quaternary deposits and hydrosoil area (former wetland areas). Source: Mogensen, Lawesson & Münier (1997), Münier & Christensen (1996).

Figure 5 (page 89) Section of Vejle County showing location of areas that are protected by §3 in the 1992 Protection of Nature Act and registered by Vejle County. The biotope types are fen (mose), fresh meadow (eng), dry grassland (commons) (overdrev), heath including wet heath (hede), salt meadow (strandeng), lake (sø). Source: Vejle County area used for agricultural production (i.e. types other than rotational land and permanent grassland) are influenced by the agricultural production in an indirect way, i.e. through transport and deposition of nutrients[4] and pesticides (heath, sand dunes, forests, bogs) or through regulation of the hydrology (mires, rivers, lakes and wet natural areas in forests). The area occupied by types of natural areas influenced indirectly by agriculture in Vejle County is outlined in Box 1.

Box 1
Types of natural areas that are influenced by agriculture in an indirect way (cf. Table 3).

Heath and sanddunes
In 1995, 1% of Vejle County was covered with heath according to the [5]§ 3 registration census in 1995 (Skov og Naturstyrelsen 1996). These areas are situated in the western part on the sandy soil (Fig 4). In 1950 the area of 'dry and wet heath' was about 7,000 ha (2%) including heath areas in other counties that later became part of Vejle County (Hove 1962).

Forest
In 1990, 12.3% of Vejle County was covered with forest which was higher than the mean percentage of the country as a whole (9.7%) (Anonymous 1994). In total, 11,700 ha were deciduous and 24,800 ha coniferous forest (Anonymous 1994). The two forest types are primarily located in municipalities with clay and sand respectively (Fig. 4), i.e. deciduous forests are located in the eastern part and coniferous forest in the western part of Vejle County.

Bogs
Thøgersen (1942) classified fens, mires and bogs greater than 5 ha and with a peat layer of at least 30 cm. These classifications were carried out in the years 1923-26 in Vejle County (Table 2). Former large bog areas were located on the sandy soil of Area III in the 'Natural and Cultural Landscape' (Thøgersen 1942). These bog areas were classified as bog class III and IV by Thøgersen (1942), i.e. bogs suitable for industrial peat production, and large bogs of lower peat quality respectively. In total, Vejle County had 1,119 ha (based on the total area of Vejle County after 1970) of class III and IV bogs (Table 2). In 1993, only four bogs were left and together comprised an area of about 18 ha, and are all located in the furthest north-western part of Vejle County (Anonymous 1994). In total, Denmark had 21 bogs comprising an area of 2,500 ha in 1993(Anonymous 1994).This is equivalent to 7 % of the area of bog classes III and IV remaining after the First World War (Table 2).

Mires, rivers and lakes.
Mires and lakes registered as §3 in the 1995 census comprised 1.9% (5,573 ha) and 1% (3,130 ha) respectively of the total area of Vejle County (Skov- og Naturstyrelsen 1996), which was less than for the whole country (2.1% and 1.3% respectively, excl. Greater Copenhagen) (Skov- og Naturstyrelsen 1996). In Vejle County, 68% of a total of 2,732 km of rivers have been classified as §3 rivers, similar to the country as a whole (69%, excl. Greater Copenhagen) (Anonymous 1994).

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[4] Critical loads of different ecosystems concerning N has been calculated/evaluated (Bak 1996, Strandberg 1996).
[5] §3 of the 1992 Protection of Nature Act.

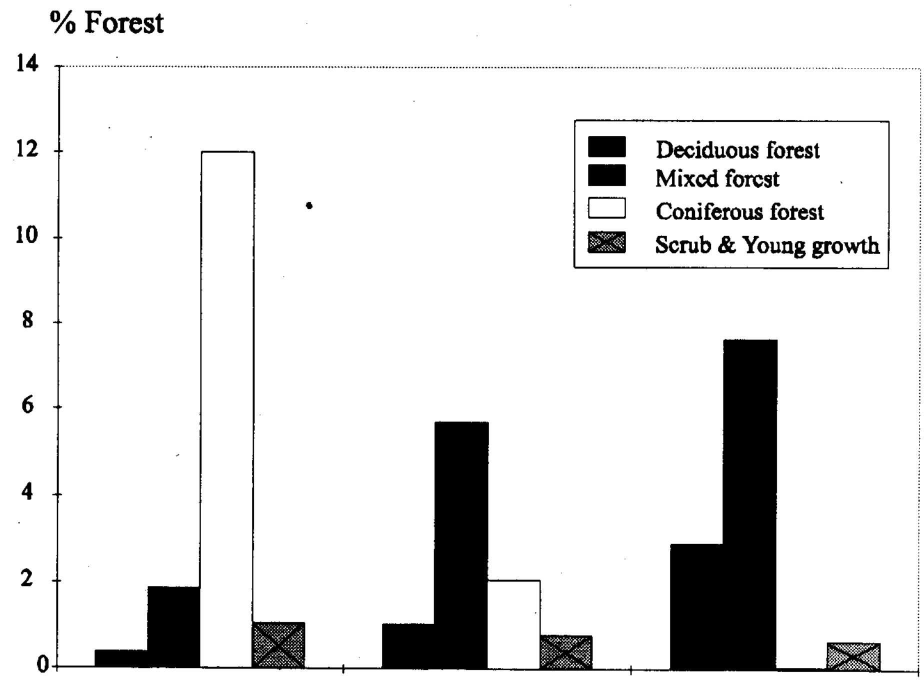

Figure 4 Percentage of four forest types (CORINE) in relation to soil types (municipality units, cf. Fig. 1), calculated as area of forest type x, located within municipalities with soil type y, divided by the total area of soil type y. Source: CORINE; GIS calculations: Bernd Münier.

The types of semi-natural areas, those dependent on grazing (wet, dry and salt meadows), are affected directly by the intensity of agricultural management. The area occupied by types of semi-natural areas influenced directly by agriculture in Vejle County is outlined in Box 2.

A small proportion of dry and wet meadows is publicly owned and extensive grazing management is therefore possible. However, the total area is very small - especially of dry meadows (commons) - thus grazing management of dry and wet meadows by private farmers is very important for the continued existence of species rich meadows in the future.

Table 2 Number and areas of fens, mires and bogs greater than 5 ha and with more than 30 cm of peat in the 1923-36 census in Vejle County and Denmark. Vejle County includes areas of the former Ribe and Aarhus counties that now are included in Vejle County. The total 130,750 ha was 4.2% of the agriculturally managed area in 1955. Source: Thøgersen (1942).

Classification of peatland	Vejle County		DK
	Number	ha	ha
I (High ash content)	36	1,675	51,816
II (Low amount of peat)	65	2,739	42,486
III (Enough peat for industrial production)	5	1,119	27,204
IV (As III, but peat of lower quality)	0	0	9,245
Total	106	5,533	130,750

Box 2
Semi-natural grasslands that are influenced by agriculture in a direct way.

Grazing dependent semi-natural areas
In 1985, grazing dependent fresh water types of semi-natural areas i.e. wet meadow and dry meadow (commons), comprised in total 46,000 and 7,600 ha respectively, for the country[6] as a whole (Anonymous 1994). Of these, 8.7% and 55 % respectively were publicly owned. In Vejle County, the areas of wet and dry meadows were estimated at 3,920 ha and 410 ha (Emsholm 1987), which corresponds to 8.5% and 5.4% respectively, of the area of wet and dry meadows in Denmark. Compared to the area of Vejle County (7% of the area of Denmark) and the topography (area with slope > 6%) the percentage area with dry meadow is very low. However, some of the dry meadow areas found in Denmark are located on flat areas in connection with salt meadows, which is a less common types of natural areas in Vejle County. A new registration of §3 protected areas in Denmark in 1995 has resulted in areas classified as wet and dry meadow that are 2-3 times greater than the registration in 1986. The differences may be caused by the lower area limit for general protection, which was changed from 2.5 ha to 2,500 m^2 with the revision of the Protection of Nature Act in 1992. However, differences in methods of registration and uncertainty of the methods may also explain some of the discrepancy. Thus some of the dry meadow areas registered in 1995 are presumed to be mosaic of dry and wet meadows and also to include areas that have been grazed over a long period, but without a continuous grazing history back to the original commons. However, the percentage of these semi-natural areas in Vejle County compared to the rest of Denmark is about the same, namely 6.2% for wet and 8.7% for dry meadows (Skov- og Naturstyrelsen 1996). The wet meadows are located primarily in the river valleys and the dry meadows on the slopes of the river valleys (Fig. 5).

The coastline in Vejle County is limited compared to other counties in Denmark. Accordingly the areas occupied by salt meadows are negligible (706 ha corresponding to 0.2 % of the total area) (Skov- og Naturstyrelsen 1996) (Fig. 5).

Table 3 Natural areas protected by the Protection of Nature Act (§ 3) in Vejle County in the 1990's (Skov- og Naturstyrelsen 1996) compared with the whole country (DK) (percentage excl. Greater Copenhagen). For comparison, total areas of wet and dry terrestrial areas and of lakes are outlined for the country in 1965 (Anonymous 1994).

		§ 3 areas 1994		Land use 1965
	Vejle	Vejle	DK	DK
	ha	Percentage of total area		Percentage of total area
Mires	5,573	1.9	2.1	'Meadows, salt meadows'
Wet meadows	6,385	2.1	2.4	7.5%
Salt meadows	706	0.2	0.9	
				'Heath, dunes, mires'
Heath	2,903	1.0	1.9	5.2%
Dry meadows (commons)	2,281	0.8	0.6	
				'Lakes and rivers'
Lakes	3,130	1.0	1.3	1.5%
Total § 3 areas	20,987 ha	7.0%	9.3%	14.2%

[6] Mapped from aerial photos and 1:25,000 maps.

According to the 1995 census, the total area of § 3 protected areas in Vejle County is 7.0% of the County area (Table 3, Fig. 5) which is less than the mean (9.3%) for country as a whole (excl. Greater Copenhagen) (Skov- og Naturstyrelsen 1996).

In total, 4.4% (13,106 ha) of the total area of Vejle County is specially protected (Statistics Denmark 1995). The percentage for the country as a whole is also 4.4%. Preserved areas include natural areas as well as landscapes that have been preserved for their geology, history, beauty etc.

2.3 Discussion and conclusion

The physical and land use factors in Vejle County are in many cases representative of Denmark as a whole: there are, for example, various soil types, agriculture is the most important land use and areas outside rotation (natural areas) are scarce. Most differences between Vejle County and Danmark as a whole are related to topography, i.e. there are more areas with a slope > 6% and fewer low-lying lands in Vejle County.

Concerning types of natural areas, Vejle County is also representative of the country as a whole. The area occupied by biotopes classified as § 3 protected natural areas, i.e. areas that have not been cultivated for a long time, is very small (7 % of the total area and about 1,900 km of rivers in Vejle County). However, it should be kept in mind that the 1992 Protection of Nature Act allows for dispensation, so the percentage of natural areas subject to long continuous management is still decreasing. Furthermore, the nature values of a §3 protected area are not guaranteed.

Among the above mentioned types of natural areas, farmers' management decisions primarily affect grassland outside rotation and small biotopes within and between fields. Of course, the nature values of the largest biotope type, i.e. the fields in rotation, are also affected. The other types of natural areas are influenced indirectly by agricultural production through drift and leaching of fertilizers and pesticides.

3 Land use and size of farms from 1955 to 1995

The interactions between agriculture and semi-natural areas are two-way, i.e. semi-natural areas need an adequate management for continued existence, but are quickly destroyed by over intensive management. Furthermore, these interactions have changed through time. In Chapter 3 some of the changes that have taken place within agriculture - and thus changes in interactions with biotype types - during the last 20-40 years are presented and discussed to identify problems and trends in the relationships between agriculture and nature values in the future to identify how nature values can be integrated into sustainable agriculture. Similarly, Chapter 4 focuses on changes in the values of different biotope types.

In this chapter, changes in agriculture in the period 1955-1995 are evaluated through a comparison of variables known or expected to influence nature values: land use, number of domestic animals, yield of cereals and diary cows, and farm size (area) (Figs 6-13). Regarding farm size, special attention has been given to the size-classes of the seven farm types defined by the Danish Institute of Agricultural and Fisheries Economics from the Agricultural Accounts Statistics 1990-1993 (Schou, Skop & Hald 1995; Skop & Schou 1996a; Skop & Schou 1996b) as they are used for the analyses in Chapters 5 and 6 of this report. To evaluate the representativeness of Vejle County, changes over the country as a whole have been included, although, to make the text more readable, data for the country as a whole are given in brackets, and not commented if similar.

As a technical consequence of the Municipal Reform in 1970, the total area of Vejle County increased by a factor of 1.27. Data have, therefore, been adjusted by this factor. The percentage changes given in the text are based directly on data from Statistics Denmark, i.e. changes from 1970 to 1995.

3.1 Land use

The total area under agricultural production has decreased, as has the area of all crop types except winter wheat, which has increased steadily, and cash crops, which peaked in the 1990's (Fig. 6). The area under spring cereals has been reduced to about one third while that of winter cereals has increased by a factor of seven to eleven (Fig. 6).

The area classified as permanent grassland has increased during the 1990's (Fig. 6) largely because 'permanent set-aside', i.e. 20 years set-aside, has been incorporated into the category 'grassland outside rotation' since 1993 by Statistics Denmark. In 1995, 47% (48%) of the areas classified as grasslands outside rotation was in reality 'permanent' set-aside areas. The nature values of these set-aside areas, are not as great as the values of old grasslands because set-aside areas have been in cultivation for years - and, indeed, are

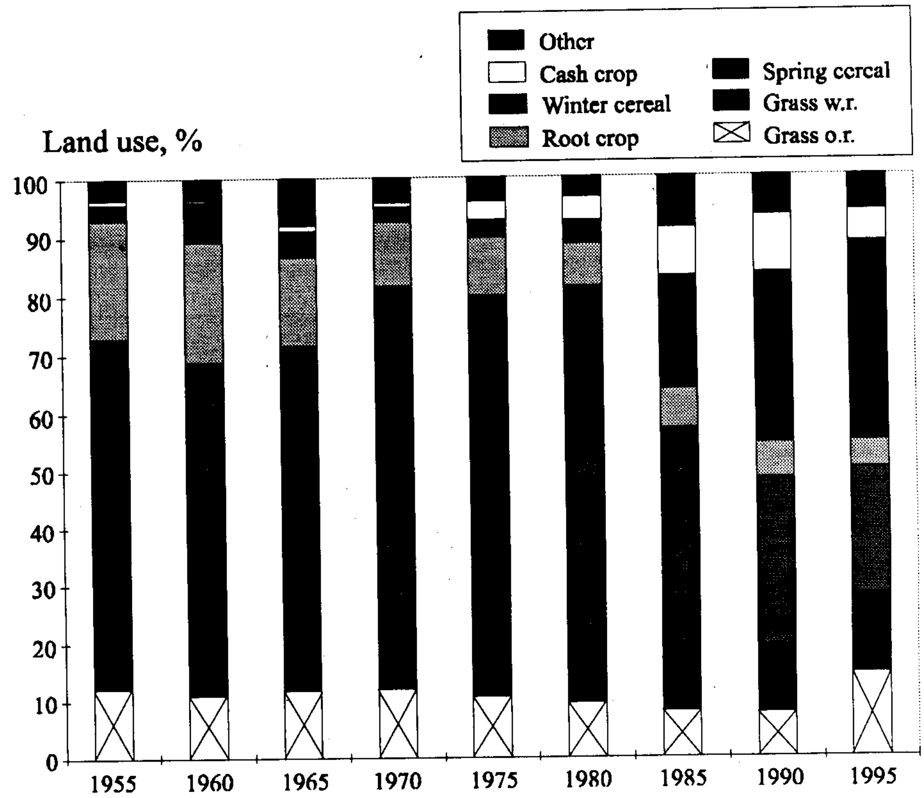

Figure 6 Changes in land use (%) of agriculturally managed land in Vejle County in the period 1955-1995. The land use groups are: Grassland outside rotation, grass within rotation, spring cereals, root crops (potatoes, sugar beets), winter cereals, cash crops (rape, grass seed), and others. Source: Statistics Denmark.

expected to return to cultivation again, as they are not protected by the §3 of the 1992 Protection of Nature Act. In reality, the area with permanent grassland (semi-natural) outside rotation has decreased dramatically, to 57% (69%) in the period 1970-1995.

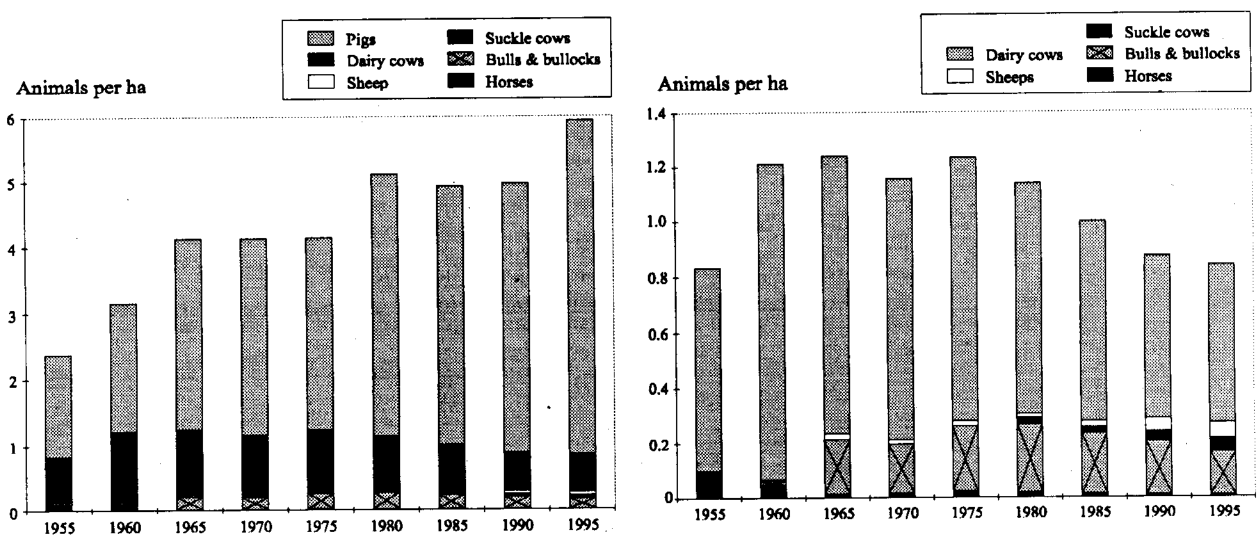

Figure 7 Changes in animal husbandry (animals per ha) in Vejle County in the period 1955-95. Left: Horses, bulls & bullocks, suckle cows including calves, sheep, dairy cows including young stock, and pigs. Right: As left figure, but excluding pigs. Source: Statistics Denmark.

3.2 Animal husbandry

Numbers of larger grazing animals held by farmers have decreased in the country as a whole and to an even greater degree in Vejle County (Fig. 7), although the number of sheep has increased. However, the increase in grazing potential (cf. Box 3) by sheep, does not make up for the decrease in grazing potential by horses and cattle (Fig. 8). The grazing potential, calculated as grazing equivalents, has fallen to 62% (78%) during the period 1970-1995. Furthermore, the number of manure-equivalents (Livestock Units) from the grazing stock has decreased during the same period (Fig. 9), although the total number of manure equivalents has increased or remained stable.

The number of pigs - a non-grazing domestic animal - has increased, more steeply in Vejle County than in the country as a whole (Fig. 7). Pigs do not benefit the nature values, but influence nature values through manure and deposition of vaporised NH_3. The total manure equivalent from pigs has increased (Fig. 9).

Box 3
Calculation of grazing potential as grazing equivalent units.

One dairy cow (including young stock) is assumed to graze a mean of 1850 SFU (Scandinavian Feed Units, 1SFU ~ 1 kg barley) per year when grazing during the summer season under normal grazing pressure on managed, rotated grassland (pers. comm. Troels Kristensen, Danish Institute of Agricultural Sciences, Foulum). On marginal permanent grassland with high grazing pressure the figure is 1480 SFU. Setting the figure for managed grassland in rotation to 1.00, the factor for permanent grassland is 0.80. The factors for suckle cows (including calves), horses, young bulls & bullocks, and ewes (including young stock) are 0.92, 0.57, 0.38, and 0.22 respectively. Multiplying these factors by the number of animals within each category and summing the values of animal categories within year gives a trend in grazing equivalent through the years• (Fig. 8). Grazing equivalent is thus defined as the number of dairy cattle (including young stock) equivalents, and based on the potential SFU consumed during the summer season at high grazing pressure on marginal grassland.

• Because of the change in area of Vejle County the number of animals has been converted to numbers per area of agricultural land.

3.3 Yield level

The yield per ha of spring barley and winter wheat in Vejle County is very close to the mean for the country as a whole, and the yield level of both crops has increased by 147-163% from 1970 to 1995 (Fig. 10). This increase took place especially from the middle of the 1980's, i.e. in the last 10-15 years and coincided with a period of increased use of pesticides (Kjølholt 1987; Paaske 1997). The yield in the years before the intensive input of pesticides and fertilizers is comparable to the organic farming yields today.

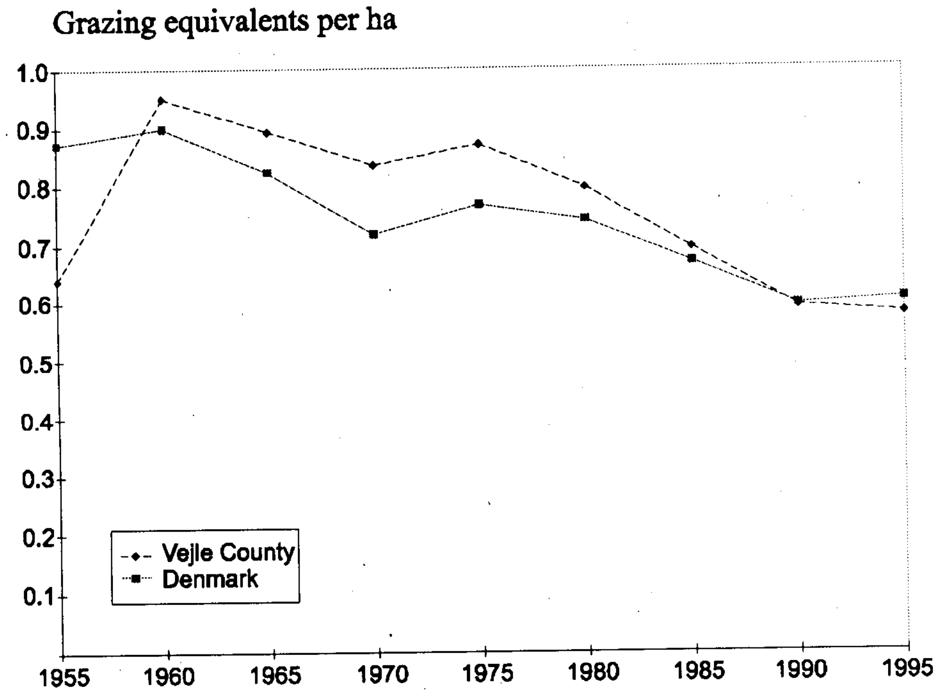

Figure 8 Changes in grazing equivalents (Cf. Box 3 for calculation method) per ha in Vejle County and in Denmark as a whole in the period 1955-1995. Source: Statistics Denmark

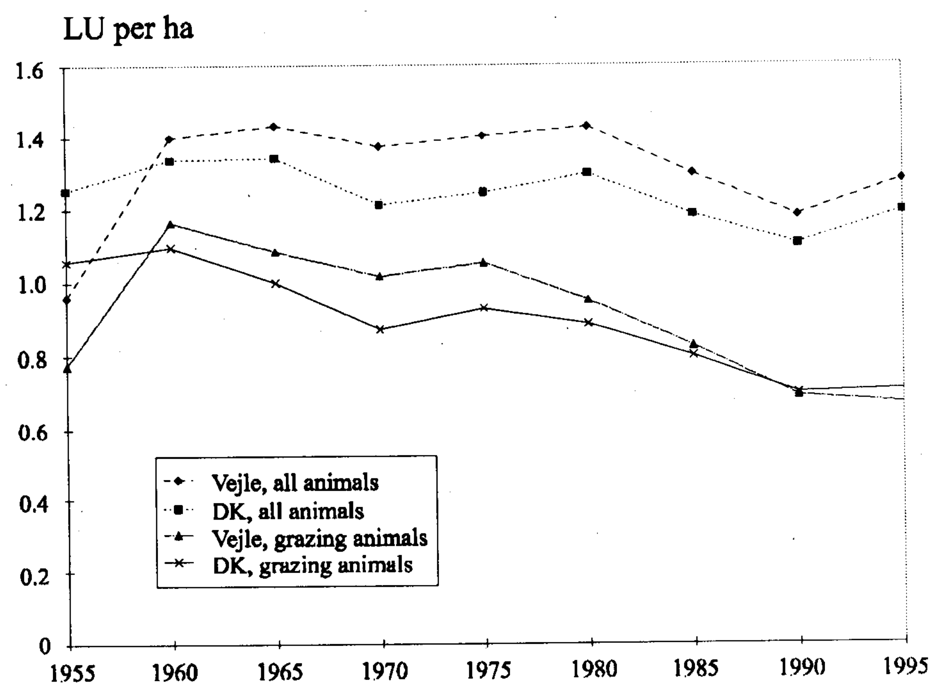

Figure 9 Changes in livestock units (1 LU ~ 108 kg N per year) per ha in Vejle County and in Denmark as a whole in the period 1955-1995. 'Grazing animals' are equal to 'all animals' minus pigs. Source: Statistics Denmark; SJFI.

Whilst the number of dairy cows including young stock has decreased, milk production per cow has increased (Fig. 11). This means that feeding of cows has intensified during this period, i.e. the dairy cow has changed from a grazer, primarily digesting cellulose, to a protein consumer.

3.4 Farm size

Farm sizes have changed since the 1950's with a decrease in small farms and an increase in large farms (Fig. 12). The reduction began with the smallest farms (5-10 ha), and continued with the intermediate size farms; in the 1990's the decrease mostly involved farms of 50-60 ha. Similarly, the increase first involved farms of 30-60 ha, but now farms larger than 100 ha have the highest rate of increase. This means that farms of the size of Part-Time farms (18 ha) (defined by the Danish Institute of Agricultural and Fisheries Economics (Schou, Skop & Hald 1995; Skop & Schou 1996b)) have decreased. Medium sized Small Cattle, Large Cattle and Large Pig production farms (59 ha, 74 ha, and 76 ha) and Large Plant farms (173 ha) have increased in number. Taking the area occupied by each farm type[1], the changes in size mean that the maximum land area theoretically (assuming that farms move from one size class to the next size class) not involved in the changes from the 1950's to the 1990's is 12% (i.e. 12% of the area still belongs to farms less than 20 ha) (Fig. 13). A change in farm size may often coincide with changes in farm type (a change from dairy production to other types). Thus within the same economic size, the area size of plant production is larger than the size of animal production (Table 9). Additionally, for the country as a whole from 1985 to 1987 15% (4,970 farms) of dairy farms changed to other types, while 931 farms joined dairy farm category (Rasmussen 1996). The change in type implies a change in composition of crop types, which includes plowing of permanent grasslands, increase in field size, and decrease in number of linear and other small biotopes (cf. Chapter 5). This means that nature values have been greatly affected by changes in farm size.

Farm size and land use together define the maximum size of individual fields (functional fields). In an area of clay soil in south eastern Zealand (Skørping), Primdahl (1994) found, using aerial photos, that the mean field size was 1.55 ha (1945), 1.70 ha (1960) and 3.36 ha (1989). No representative investigation of changes in field size in Denmark has been published. As farm size has increased, and linear biotopes have been removed - less so in the most sandy areas in the western part of Denmark - it is assumed that the size of the functional field has in general increased. Therefore, the mosaic of the landscape has changed, and farmland animals requiring different field types within their home range are most affected, for example, brown hare, partridge, and pheasant.

[1] Comparing the total area (A_t) of the seven farm types the multiple-factor of the size of a Part-Time farm will follow: Part-Time farm of 18 ha (A_t=1); economic Small Cattle, Small Pig, and Small Plant farms of 32 ha, 34 ha, and 59 ha (A_t=2 & 3); economic Large Cattle and Large Pig farms of 74 ha and 76 ha (A_t=4); economic Large Plant farms of 173 ha (A_t=10).

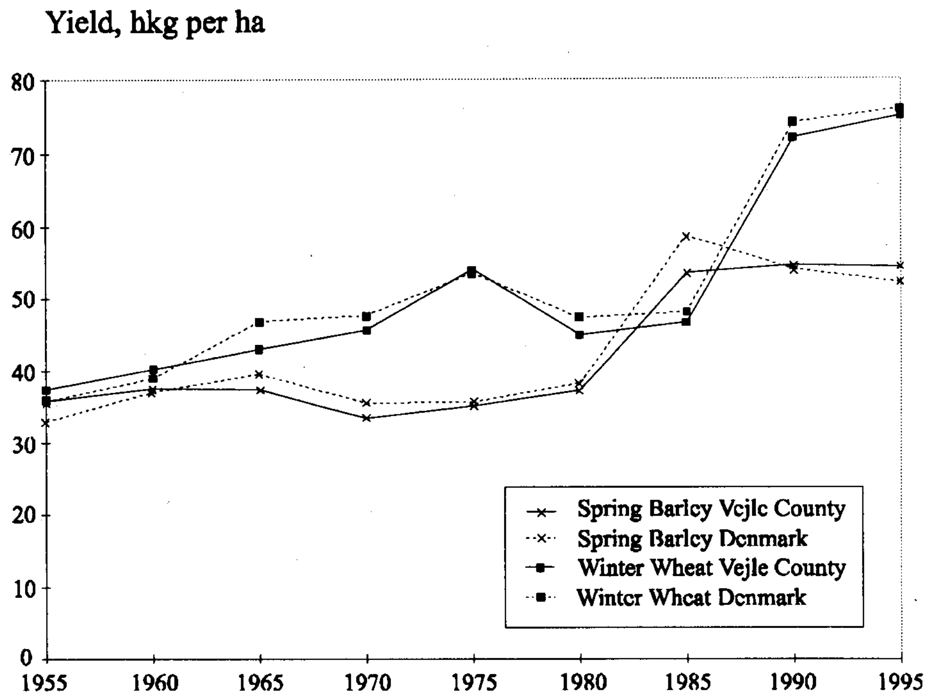

Figure 10 Changes in cereal productivity (hkg per ha) of spring barley and winter wheat in Vejle County and in Denmark as a whole in the period 1955-1995. Source: Statistics Denmark.

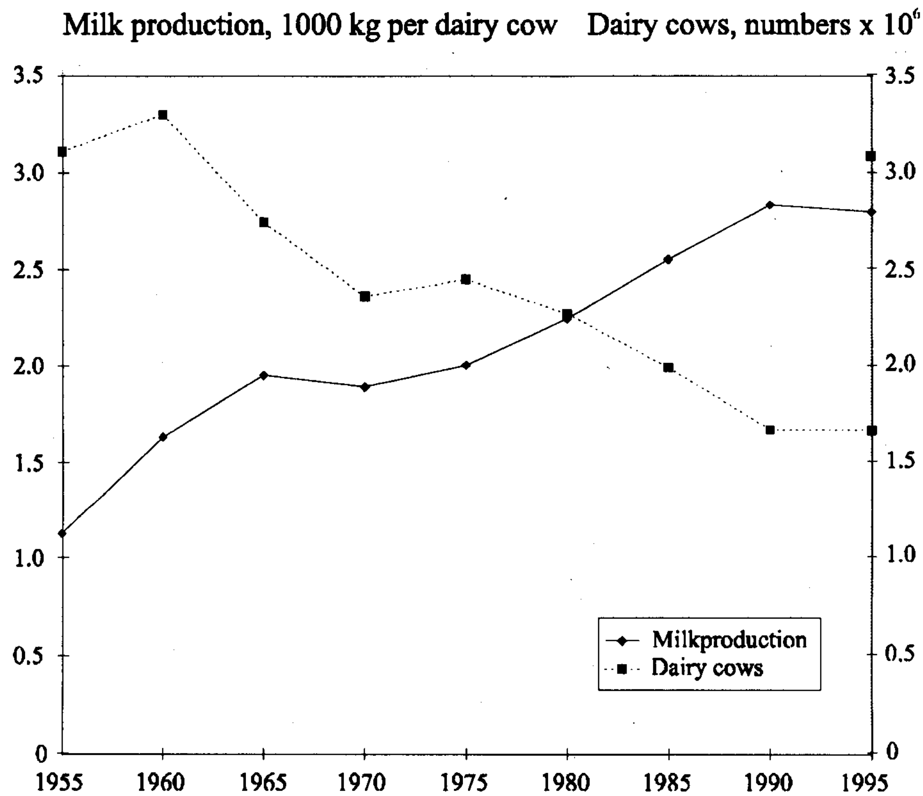

Figure 11 Changes in total number of dairy cows including young stock (x 10^6) and yearly milk production (1,000 kg) per dairy cow including young stock in Denmark in the period 1955-95. Source: Statistics Denmark.

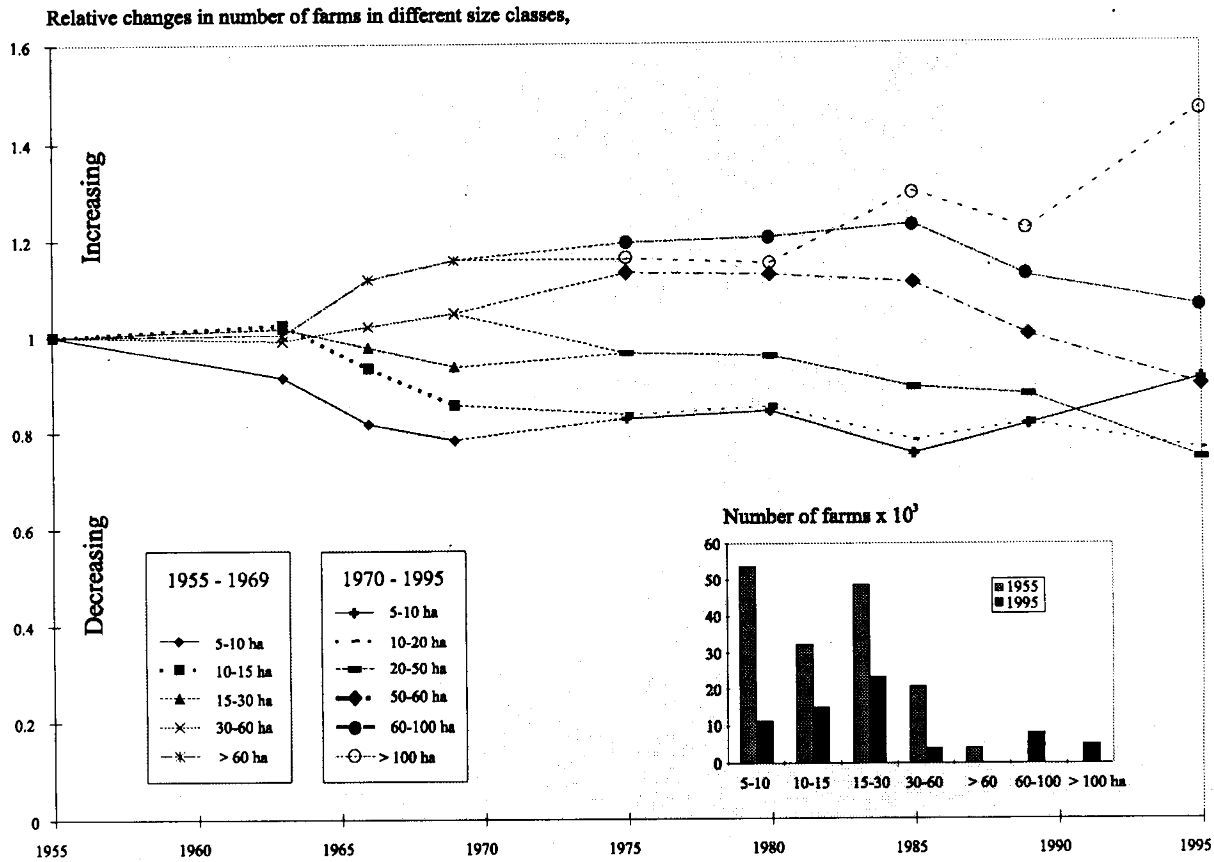

Figure 12 Relative changes in Denmark of number of farms within different size classes during a five year period (N_t/N_{t-5}). Only farms >5 ha are included. The size classes, corresponding to the farm types defined by the Danish Institute of Agricultural and Fisheries Economics, could be established from the statistics from 1970 and onward only. Inset shows the actual number of farms within the different size classes in 1955 and 1995. Source: Statistics Denmark.

3.5 Discussion and conclusion

Vejle County is representative of Denmark as a whole with regards to the main changes in agriculture from the 1950's to the 1990's. Compared to the country as a whole a larger reduction in grazing potential and larger increase in the number of pigs has taken place in Vejle County. The changes are related to intensification and specialisation and result in a circa 150 % increased yield of cereals per ha; a 200 % increased milk yield per cow; a change in animal stock from grazing to protein consuming animals resulting in a reduction of grazing potential while the production of manure is unchanged; a change in cropping from a combination of spring cereals and permanent grasslands (green in winter) to winter cereals; an increased farm size; and an increase in field size.

Increased farm size means amongst other things, that decisions taken by one farmer have increasing impact on the landscape and that the farmer is managing large areas that did not belong to his family. This is likely to result in an emotional detachment from his land as the memory *'of the special flowering meadow in the farmers' childhood'* will no longer play a role in management decisions. This, too, must have great impact on the quantity and quality of natural areas.

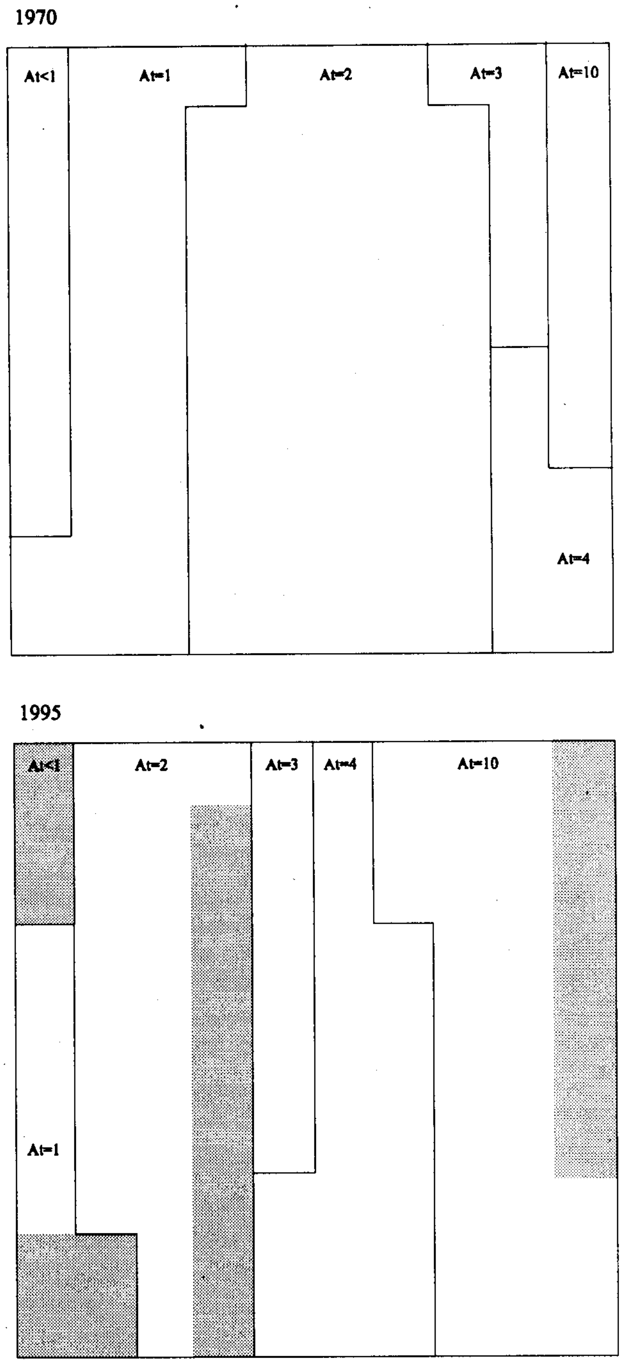

Figure 13 Percentage of the agricultural area occupied by the different farm size types (A_t=1, 2, 3, 4, 10, Cf. Table 9) in 1970 and 1995. The area of the different farm types theoretically not included in changes of farm size is depicted by shading. Only farms >5 ha are included. Source: Statistics Denmark and the Danish Institute of Agricultural and Fisheries Economics.

4 Agriculture and nature values of cultivated fields, permanent grasslands and small biotopes

This chapter presents and discusses some of the changes in the flora of biotope types in the agricultural landscape - changes that have taken place at the same time as the changes in agriculture described in Chapter 3 - to identify the problems involved in maintaining nature values in the landscape and determine how nature values can be integrated into sustainable agriculture.

4.1 Changes in qualitative and quantitative nature values in response to intensification

Documentation of the wild flora (weed) in cultivated fields before the intensification period, i.e. in the 1960's, and the changes that have taken place since is poor. The changes in the vegetation and in the seed bank have been documented by Andreasen et al. (1996) and Jensen & Kjellsson (1995) respectively. Andreasen et al. (1996) found that the mid field species density of the 67 species most common in 1967/70 had in general been reduced by about 60% twenty years later - the reduction was higher in winter wheat than in spring barley (Andreasen et al. 1996) (Table 4).

Jensen & Kjellsson (1995) found that the seed bank had halved from 1964 to 1989, and of the 41 most frequent species in the seed bank, a total of 27 could be tested, of which 11 had decreased. A comparison of the results from the two surveys shows that assessment of changes

Table 4 Potential biodiversity of weed flora (unsprayed conditions) in different crop types in 1987/89 (Andreasen 1990) and species density (number per 0.1 m^2; available for five crop types only) in 1967/70 and 1987/89 (Andreasen et al. 1996).

Crop type	# Fields investigated 1987/89	Total # species 1987/89	Species density 1967/70	Species density 1987/89
Spring sown crops	May-June assessment			
Spring barley	44	85	6.9	2.9
Peas	43	74		
Fodder suger beet	40	73		
Commercial suger	47	65		
Spring rape	45	61	5.8	2.7
Autumn sown	Autumn assessment			
Winter rye	42	53	6.6	2.8
Winter barley	37	47		
Winter wheat	41	45	5.8	2.1
Perennial crops	May-June assessment			
Grass ley (2nd year)	44	48	3.4	1.5

is more conservative for the seed bank than for the vegetation (Table 5). Thus, the more specific aspects of the wild plant vegetation (weeds) in different crop types integrate in the seed bank, thereby, damping the changes in the seed bank. However, the seed bank much better reflects the changes in non-annual species, as some of these do not germinate in annual crop types, but have their niche in gaps in perennial grass fields. The lack of significant changes in the low frequency 'Other' group - including 27% of the non-annuals - is caused by a too sparse occurrence for testing rather than no-effect on this group, as the total species density has decreased. Consequently, the large decrease in both plant density and species density (biodiversity) of wild plant species in rotational fields has been a general trend, especially for the non-annual species occurring in perennial grasslands.

Another way of describing the wild flora of fields before the intensive use of pesticides and fertilizers is to include fields that have been farmed organically for a long time. The flora and fauna in organically and conventionally farmed cereals has been compared by Hald & Reddersen (1990) and re-evaluated by Reddersen (In Press) and Hald (In Prep). The botanical results showed that all the variables that differed between the two systems had highest values - often several times higher - in organic systems, with four exceptions: total biomass, biomass of the crop, relative density of a single non-grass taxon and of grasses. The differences between the two systems were larger in mid fields than in the crop margins. The arthropod study showed that total density, species density, total biomass and number of arthropod bird food items were consistently and often significantly highest in organic fields. These results are excluding aphids and Collembola.

The results from the 1960's (Andreasen et al. 1996) and from the organically farmed cereal fields (Hald & Reddersen 1990) are used as a reference for the cereal fields in the 1950's-1960's to illustrate the dramatic changes that have taken place in the last 20-40 years (Fig. 14).

Table 5 Comparison of floristic changes from 1967/70 to 1987/89 of the 67 most common species in the vegetation of five crop types in the 1967/70 survey (Andreasen et al. 1996) and the changes observed in the seed bank (Jensen & Kjellsson 1995).

Fate of species	Decrease Veg. and seed bank	Decrease Vegetation, only	Increase Veg. or seed bank	Others
# Species in the vegetation 1967/70	18	38	2	10
# Non-annuals	4	15	0	7
Mean # of crop types out of five with changes	3.6	2.5	1.0	-
Max. frequency in five crop types	27	14	8.5	3.1

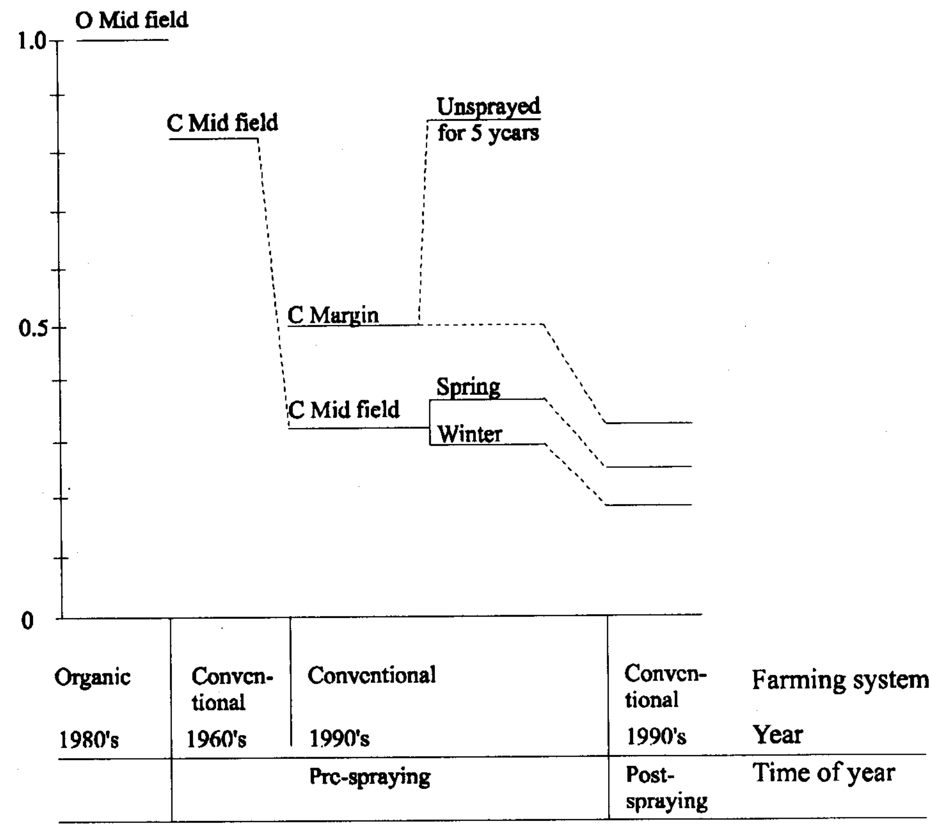

Figure 14 Outlines of relative density of wild plants in organically[1)] (summer aspect) and conventionally farmed cereals as function of year (1960's and 1990's)[2)], location in the field (crop margin, mid field)[1)], cereal type (spring barley, winter wheat)[3)], time of the year (pre- and post herbicide application, representing potential and actual weed vegetation, respectively)[1)], and five years of unsprayed crop margins[4)]. E: Ecological, C: Conventional. Source: (1): Hald & Reddersen 1990, (2): Andreasen 1990, (3): Hald (Submitted), (4): Hald et al. 1994.

The composition of the species characteristical for dry grassland types (commons) of medium pH and managed with extensive grazing, and for grassland types improved agriculturally with fertilizer, plowing and reseeding has been analysed and re-evaluated by Ejrnæs and Bruun (1995a, 1995b). A comparison of the species composition of ten relevés from both management types on clayey sand, shows that only 14% (31 species) of the total species list (119 species) were shared (Fig. 15). The number of species was much higher on improved grasslands than on original, old types (Fig. 15). However, 48% and 23% of species found on the improved and old grasslands respectively, were weed species occurring on fields in rotation. The number of biotope specific non-weed species of the two types were 34 and 27 species in old and managed grasslands respectively. A full species list is given in Appendix 1.

Meadows are often drained and improved with fertilizer and sown culture grasses to increase the agricultural value. Wet and slightly drained meadows, and permanent, slightly improved grasslands do have some species in common, but each habitat has its own assemblage of species and the dominant species are different.

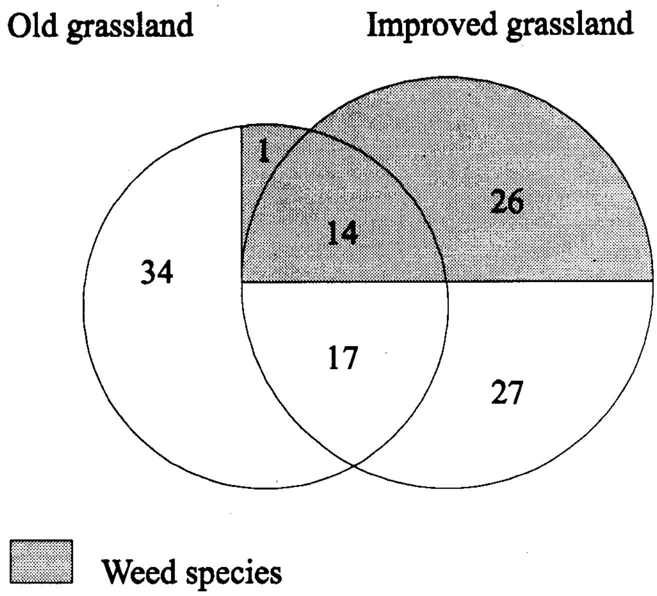

Figure 15 Comparison of number of species shared by ten old (unimproved) and ten improved dry grasslands both on clayey sand (Mols Bjerge). Source: Ejrnæs & Bruun (1995a), Ejrnæs & Bruun (1995b), and Ejrnæs (pers. com). The species have been divided into weed (shaded area) and non-weed species. Species noted as weeds are species occurring with F% > 0.2 in rotational fields and 2nd year grass leys in spring or summer analyses (Andreasen 1990). The numbers refer to the number of species within each category. A species list is given in Appendix 1.

The wet mesotrophic meadows are dominated by *Agrostis stolonifera* and *Alopecurus geniculatus* (Kryb-Hvene & Knæbøjet Rævehale), the moist meadows are dominated by *Deschampsia caespitosa, Poa trivialis, Holcus lanatus,* and *Juncus effusus* (Mose-Bunke, Alm. Rapgræs, Fløjlsgræs & Lyse-Siv), and the moist and improved meadows are dominated by *Ranunculus repens, Potentilla anserina, Lolium perenne,* and *Trifolium repens* (Lav Ranunkel, Gåse-Potentil, Alm. Rajgræs & Hvid Kløver). A full species list is given in Appendix 2. This change in dominant species indicates a shift into drier and more eutrophic conditions. Slight drainage and improvement increase the total number of species (Table 6). However, most of the increase in species number concerns species from drier and more eutrophic biotopes, and most of the species occur widely in the landscape. The species from wet biotopes are more restricted in their distribution and become less important in the vegetation through the sere Wet -> Moist, Improved (Table 6). The most intensively improved grasslands, i.e. grasslands in rotation, do have some species in common with the meadows. Among the 48 species found in 2nd year ley (Andreasen 1990), nine wild species and five cultivated species were also found in meadows. Whilst 87% of the species occurring in the 2nd year ley were annual species which also occur in cereals, only a few species from the meadows occur in annual crops.

Table 6 Comparison of species occurrence in three types of mesotrophic meadows found by TWINSPAN from a national survey (Mark 1997): 1)Wet, 2) Moist, i.e. slightly drained and fertilized, 3) Moist and further improved meadow. The species list from each of the three types of meadow is drawn from 10 samples each of $1m^2$ and from different localities. The table shows the sum of scores of all observed species within a species group (Van der Maarel abundance scale 1-9). Species that occurred in one meadow type only, and with sum of scores < 4 are excluded from the sum of scores, but included in the number of species. Source: Mark (1997). TWINSPAN analysis by Bettina Mogensen. The full species list is given in Appendix 2.

Meadow type	Wet	Moist	Moist Improved
Number of species per $1m^2$	6.7	9.7	10.3
Total number of species in 10 m^2	34	42	52
Species group		Sum of Scores	
Species in Wet, only	12	0	0
Species in Wet AND Moist AND Moist, Improved Species in Wet AND (Moist OR Moist, Improved)	256	292	198
Species in Moist, only	0	31	0
Species in Moist AND Improved	0	59	53
Species in Moist, improved, only	0	0	79

Similar reference-data on the effect of intensification is not available for the small biotopes in the agricultural landscape; only analyses of road verges (Hansen & Jensen 1972), and of narrow grass verges between fields (Sepstrup 1974) are available. Therefore, these data have been supplemented with data from hedgerows in the contemporary agricultural landscape (Hald et al. 1988; Hald et al. 1994; Jensen and Dalsgaaard 1993) (Table 7). It should be noted that the small biotopes - in contrast to the fields in rotation - are habitats of perennial species, that the verges were not a habitat of annual (A) and biennial (B) species, that the field boundaries were a habitat of species indicating high nutrient conditions (N), that some of the species preferring field boundaries represented woodland species (W and W W), and that some of the species preferring verges represented species of unshaded low growing vegetation types and species from relatively nutrient poor conditions (L). The differences in W and L species clearly reflect differences in the structure and management of the two different types of small biotopes. As the analyses by Sepstrup (1974) were included in the ranking of the species in field boundaries, the differences concerning N and A/B species seems to be an effect of being adjacent to agricultural fields.

Although linear small biotopes such as hedgerows are mostly next to fields in rotation, the number of species shared with the cultivated field are few (Mikkelsen 1970; Marshall 1989; Hald et al. 1994; Marshall & Arnold 1995). Comparing the species composition in linear small biotopes with those of permanent grasslands, some of the species are shared - mostly the L-species and those from the

Table 7 Mean rank of frequently occurring species observed in the grass-herb layer of two types of small biotopes. Field boundary data are from hedgerows analysed by [1]Hald et al. (1988), [2]Hald et al. (1994), [3]Jensen & Dalsgaard (1993), and [4]Jørgensen (1983), and from treeless boundaries analysed by [5]Sepstrup (1974). Verge and slope data are from verges and slopes of roadsides analysed by [6]Hansen & Jensen (1972). The species were ranked within each investigation, and a mean rank has been calculated for the two biotope types. The species included in the table occurred in both unsprayed and reference parcels[ref 1]; in >40% of the parcels[ref 2]; with >40% constancy[refs 3 and 5]; were among the 10 most frequent species[ref 4]; in >15% of the samples[ref 6]. Remarks: Autecology of species occurring with a mean rank <6 in one of the biotope types and a mean rank >10 in the other, or species that occurred in one type only have been evaluated. A: Annuals; B: Biennials; N: Species growing in nutrient rich places; L: Species growing in light open vegetation or in relatively nutrient poor places; W: Woodland species; W W: Wet growing woodland species.

Species Danish names	Latin names	Field boundary[1-5] Mean rank	Verge & slope of roads[6] Mean rank	Remark
Alm. Kvik	Agropyrum repens	12.81	21.00	
Alm. Hundegræs	Dactylis glomerata	9.38	26.00	
Eng-Rapgræs	Poa pratensis ssp.pratensis	7.63	21.50	
Vild Kørvel	Anthriscus sylvestris	6.88	6.50	
Rød Svingel	Festuca rubra	5.75	28.00	L
Stor Nælde	Urtica dioica	5.75	-	N
Burre-Snerre	Galium aparine	5.25	-	A N
Draphavre	Arrhenatherum elatius	5.13	14.25	N
Ager-Tidsel	Circium arvense	5.00	3.00	
Alm/Stortoppet Hvene	Agrostis tenuis/gigantea	4.69	25.50	-
Mælkebøtte	Taraxacum spp.	4.31	26.00	L
Lund Rapgræs	Poa nemoralis	3.19	-	W
Grå Bynke	Artemisia vulgaris	3.06	-	N
Alm. Røllike	Achillea millefolium	3.00	29.00	L
Feber Nellikerod	Geum urbanum	2.63	-	W W
Alm. Rapgræs	Poa trivialis	2.63	7.50	
Krybende Hestegræs	Holcus mollis	2.38	14.50	L
Alm. Fuglegræs	Stellaria media	2.38	-	A
Vorterod	Ficaria verna	2.31	-	W W
Enårig Rapgræs	Poa annua	2.13	-	A
Snerle-Pileurt	Polygonum convolvulus	2.00	-	A
Haremad	Lapsana communis	1.88	-	A
Hvid Anemone	Anemone nemorosa	1.56	-	W
Regnfang	Tanacetum vulgare	1.56	-	-
Mark Forglemmigej	Myosotis arvensis	1.31	-	A
Ager-Padderok	Equisetum arvense	1.13	9.50	N
Skvalderkål	Aegopodium podagraria	1.00	-	N W
Ager-Snerle	Convolvulus arvensis	1.00	-	N
Døvnælde	Lamium album	1.00	-	W
Lav Ranunkel	Ranunculus repens	1.00	16.75	L
Tveskægget Ærenpris	Veronica chamaedrys	1.00	5.50	
Vedbend-Ærenpris	Veronica hederifolia	1.00	-	A
Korbær	Rubus caesius	0.88	-	W
Eng-Rottehale	Phleum pratense	0.81	7.50	
Hulsvøb	Chaerophyllum temulum	0.75	-	W
Bølget Bunke	Deschampsia flexuosa	0.69	-	L
Gederams	Chamaenerium augustifolium	0.63	-	N W
Alm. Stedmoderbl.	Viola tricolor	0.63	-	A
Alm. Torskemund	Linaria vulgaris	0.56	2.00	
Desmerurt	Adoxa moschatellina	0.44	-	W W
Skovarve	Arenaria trinervia	0.44	-	W
Kruset Tidsel	Carduus crispus	0.38	-	B
Alm. Hønsetarm	Cerastium fontanum	0.38	17.00	A

Table 7 Continued

Species Danish names	Latin names	Field boundary[1-5] Mean rank	Verge & slope of roads[6] Mean rank	Remark
Hvidmelet Gåsefod	Chenopodium album	0.25	-	A
Muse-Vikke	Vicia cracca	0.25	13.50	L
Fåre Svingel	Festuca ovina	0.13	-	L
Skov-Galtetand	Stachys silvatica	0.13	-	W
Lancet Vejbred	Plantago lanceolata	-	24.50	L
Blåklokke	Campanula rotundifolia	-	18.00	L
Hvid Kløver	Trifolium repens	-	17.00	L
Høst-Borst	Leontodon atumnalis	-	16.00	L
Håret Høgeurt	Hieracium pilosella	-	11.50	L
Alm. Rajgræs	Lolium perenne	-	9.00	N
Alm. Syre	Rumex acetosa	-	9.00	L
Glat Vejbred	Plantago major	-	7.50	L
Rødknæ	Rumex acetosella	-	7.00	L
Eng Svingel	Festuca pratensis	-	4.50	L
Kongepen	Hypochoeris sp.	-	4.00	L
Hvid Okseøje	Chrysanthemum leucanthemum	-	3.50	L
Håret Frytle	Luzula pilosa	-	3.50	L
Bidende Ranunkel	Ranunculus acris	-	2.50	L
Gåse Potentil	Potentilla anserina	-	2.00	L
Humle Sneglebælg	Medicago lupulina	-	1.50	L
Fløjlsgræs	Holcus lanatus	-	1.25	L
Rødkløver	Trifolium pratense	-	1.25	L
Alm. Kællingetand	Lotus corniculatus	-	1.00	L
Blåhat	Knautia arvensis	-	0.50	L

grassland - and least between hedgerows and old grasslands (Table 7). As expected, the number of shared species between the moist meadows, linear small biotopes and grasslands are few, as the linear small biotopes represented, like dry grasslands, are mostly dry biotopes. However, linear biotopes such as ditches and river banks may have species in common with moist meadows. The fact that plant species found in different biotopes in the agricultural landscape are very different was also confirmed by Fritz & Merriam (1994), who found a low similarity between the flora of the field layer of hedgerows and forest edges, both adjacent to fields in the same geographical area.

4.2 Crop yield and nature values

The grain yield of cereals is positively related to the biomass of the crop, and negatively related to the biomass of weeds (Svensson & Wigren 1982; Christensen & Rasmussen 1996; Jensen 1996; Christensen & Rasmussen 1997). The higher biomass of the crop has an effect on the wild flora through interception of light (Kleijn & van der Voort 1997) and higher level of competition for nutrients and water. In a comparative study of organic and conventional cereal fields, the biomass of the crop was found to be 34 % higher in conventionally than in organically farmed cereals (Hald In Prep). The weed biomass in g dw per m^2 (median) was 68 in organic and 14.4 in conventional cereals. The yield in organic cereal fields is about 80-85% of that in conventional cereals (Kruse et al. 1987). In a comparative study of unsprayed and sprayed 6 m wide crop margins, the weed biomass increased from 20 to 40 g dw per m^2 (geometric mean, n=8 field pairs) from the first to the fifth consecutive year of unsprayed conditions (Hald et al. 1994). The biomass in the sprayed margins was not measured, but may have been about 5-15 g dw per m^2 judging from results elsewhere in sprayed cereals (Hald et al. 1988, Hald et al. 1994). Crop yield loss in unsprayed compared to sprayed crop margins was 15% in spring barley and and 26% in winter wheat (Hald et al. 1994). This means, that maintaining a mean weed biomass of about 40 g per m^2 (range: 20 to 68) corresponds to a decrease in crop yield of 15% to 26% , depending on crop type, and corresponds to a resulting yield per ha of 40-46 hkg in spring barley and 56-64 hkg in winter wheat. The lower yield values correspond to the yield in 1980 (spring barley) and in 1985 (winter wheat) (Fig. 10). Reduced crop yield occurs through both decreased pesticide use and lower input of fertilizers[1], which are both beneficial for the nature values (Hald & Lund 1994). Increasing the amount of fertilizer thus increases the biomass of the crop and decreases the weed biomass under unsprayed conditions (Hald 1994; Jørnsgård et al. 1996).

A comparison of the visibility of the inflorescence of wild plants in the vertical crop layer of organic and conventional cereals showed that dicotyledonous species which flower in the upper crop layer made up a larger share of the occurring species in organically farmed cereals (Hald In Prep). In conventional cereals, dicotyledonous species which flower at the bottom of the crop layer and grasses were relatively most numerous. Thus the lower biomass of the crop in organic cereals allows flowers of wild plants to be present throughout the vertical profile of the crop, thereby making them more available to flying insects and increasing the aesthetic value of the agricultural landscape.

The biomass or agronomic value and biodiversity in meadows (outside rotation) has been compared. In general there is a trade-off between productivity and nature value measured as biodiversity of biotope specific species (Daget & Poissonet 1971, Grime 1979; Schiefer 1984; Berendse et al. 1992; Rychnovská 1993; Huston 1994; Nösberger et al. 1994). This trade off is based amongst other things on the different strategies of the species constituting the vegetation in high and low productivity grasslands. High productivity grasslands are characterised by species that germinate rapidly and at low temperatures. The species from less productive grasslands germinate more slowly and often need fluctuating temperatures and therefore more open stages in the vegetation (Olff et al. 1994). Ellenberg (1986) pointed out that eutrophication leads to the eradication of all species which are adapted to oligotrophic habitats. For example, the species composition of German grassland has changed towards species which originated from nutrient-rich sites, and species richness has decreased dramatically in the past decades due to eutrophication (Schulze & Gerstberger 1994).

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[1] On clay soil a reduction of 50% in N fertiliser input in spring barley is necessary for a reduction in yield to 85% (Paaby et al. 1993).

4.3 Crop type and nature values

The crop grown on fields in rotation influences the potential wild (weed) flora in the field (Andreasen et al. 1996; Hald Submitted), and thereby the arthropods associated with the wild plant species. Furthermore, the bird fauna is affected indirectly by the availability of herbivorous arthropod food items (Hald & Reddersen 1990), and directly through the seeds and green parts produced by the different weed species (Christensen et al. 1996) and eaten by birds.

In nine different rotational crop types, the total number of species of wild plants and species density decreased in order: spring sown, autumn sown, undersown/ley (results from analyses of 10 times 0.1 m^2 of unsprayed mid field areas) (Andreasen 1990; Andreasen et al. 1996) (Table 4). However, the ley fields contained biennial and perennial dicotyledonous species that do not reproduce in crop types used in annual rotation (cf. Table 6). Furthermore, undersown dicotyledonous species themselves, for example Fabaceae (leguminous) species, may benefit arthropods acting as a substitute for wild plants (Hald & Reddersen 1990; Hald et al. 1994).

The weed flora in unsprayed spring and winter cereals has been compared by Hald (Submitted). The results showed that plant and species density, and accumulated species richness were lower in winter than in spring cereals. Furthermore, species occurring in different densities in the two cereal types occurred preferentially in spring cereals. This was also the case when adjusting for the higher plant density in spring cereals. Most (93%) of the species found in cereals are able to germinate in the spring, while less (65%) are able to germinate in the autumn. The species occurring preferentially in spring cereals mainly germinate in the spring. Floristic similarity was higher both among spring cereal fields and between spring and winter cereal crops in different years within the same field than among winter cereal fields. Concerning herbivorous arthropod bird food items, the results by Hald (Submitted) shows that plant species which are important food resources for herbivorous arthropods also occurred at a higher density in spring than in winter cereals. The change in land use from spring to winter cereals (Fig. 6) thus not only involves an immediate reduction of more than 25% in the density of plants and species (cf. Fig. 14), but also a change and increased uncertainty in the composition of the wild plant species in the vegetation.

A change from spring sown to autumn sown crops (Fig. 6) implies that more areas are ploughed in the autumn. This has a detrimental effect on arthropods such as sawfly larvae, which hibernate in the soil of stubble fields and in the spring move as adults to new cereal fields. Sawflies are included among the preferred diet of grey partridge chicks (Potts 1986).

4.4 Nature values of crop margin versus mid field of cereal fields

A comparison of mid field and crop margin in conventional cereals showed a mid field:margin ratio in plant density prior to herbicide spraying of 0.66 (Hald In Prep) (Fig. 14). The species density was also highest in the crop margin. In organic cereals, the high plant and species density in the crop margin was maintained throughout the field. The crop margin may contain more sparsely distributed species occuring as a residual population (Wilson 1989). Andreasen et al. (1996) found a decrease in mid field species density of 60% from 1967/70 to 1987/89. Assuming no gradient in the occurrence of wild plants from crop margin to mid field in 1967/70 as was the case in the organic farmed cereals (Hald & Reddersen 1990), it is clear that the occurence of weeds in the crop margins has also been reduced, but to a lesser degree than mid field (Fig. 14). In general, the yield is lower in the crop margin than in the mid field (Hald et al. 1994). The reasons for this could be poor soil structure and lower fertilizer input in combination with competition from the hedgerow. The lower crop biomass in the crop margin increases the possibility of a higher seed production and seed input to the seed bank.

Thus, removal of hedgerows and other linear biotopes may after some years result in a reduction in the density of plants and species in the former crop margin to the mid field level. However, the opposite - the build up of an enriched 'crop margin' flora in connection with the establishment of a hedgerow or other linear biotope - is not only dependent on a lower crop yield in the crop margin. The species belonging to the (residual) crop margin flora are only expected to reoccur if they are able to recolonize from a nearby population.

4.5 Nature value of unsprayed crop margins of cereal fields

Unsprayed crop margins protect the potential flora in the crop margin, i.e. the established seedlings, and may result in an increase in plant density over time. Thus continuously unsprayed crop margins in cereal fields over five years increased the potential plant density of dicotyledonous species by a factor 1.7 while the total number of grass seedlings did not increase during the five years of unsprayed conditions in crop margins (Hald et al. 1994). This increase in potential weed vegetation brought the level of wild plants in unsprayed crop margins of conventionally farmed cereals close to the density of wild plants found throughout organically farmed fields (Fig. 14). Spraying affects the germinated vegetation of wild plants, resulting in a summer flora with species density reduced to two thirds and plant density (measured as Frequency Sum) reduced even more (Hald Submitted) (Fig. 14). Spraying with herbicide (and fungicide) alone caused a large part of the decrease in the arthropod fauna found in sprayed compared to unsprayed crop margins (Hald et al. 1994). The reduction in crop yield caused by unsprayed conditions in crop margins was 26% in winter wheat and 15% in spring barley of the yield in sprayed crop margins (Hald et al. 1994).

The similar net reduction in yield (minus cost of spraying) was 9-18%. Converting to reduction in hkg it should be noted that the crop yield in the crop margin compared to mid field is generally lower (50-85% of the mid field yield) (Hald et al. 1994).

4.6 Animal husbandry and nature values

As mentioned in Chapter 2, high biodiversity of grassland species is dependent on extensive grazing continued over many years, i.e. grazing every year with a grazing pressure that does not require food supplement in bad years, and no application of fertilizers and pesticides. Especially, at naturally low nutrient levels (oligotrophic/mesotrophic or chalk soil) additional input of fertilizers is deleterious. Cattle, bull & bullocks, sheep and goats are potential grazers, however, together with pigs, they also produce manure, and thereby are a potential source of eutrophication of terrestrial biotopes and leaching of nitrate. The total amount of manure produced has been stable since the 1960's while the amount of manure produced by grazers during the same period has decreased (Fig. 9). Today, half of the manure produced originates from grazing animals, while the other half is produced by pigs.

It has to be stressed that not all potential grazers do graze. Only animals from organic farms are certain to be found grazing in a field, since grazing is part of the regulations for organic farmers. Furthermore, it is difficult to maintain high milk production on grazing of the relatively more extensive grasslands outside rotation. Therefore, the potential grazers of areas outside rotation do not include diary cows - on either conventional or organic farms.

4.7 Discussion and conclusion

Spring sown cereals have been cultivated in Denmark since farming became established, and the flora in annually rotated fields is, therefore, mostly adapted to and dependent on spring sown cereals. Consequently, the proportion of rotational areas suitable for these species has been reduced in space and discontinued in time. Furthermore, space for the wild flora within fields has been reduced as a consequence of higher crop yields. Crop margins contain the highest level of biodiversity of arable wild plants.

Space for the floral element of perennial grassland has been reduced: both the areas of grassland outside rotation and the grazing potential has decreased; high yielding dairy cows are only able to graze on improved grassland (mostly high yielding grass in rotation) leaving very little space for wild plants even on grassland outside rotation. Especially those species belonging to unimproved, moist and wet meadows and dry grasslands are not able to survive without special measures being taken to protect them.

Furthermore, the more widespread plant species growing in the perennial vegetation of small biotopes within the agricultural landscape are affected by agriculture: biotopes are destroyed and the area taken into cultivation or they are influenced by fertilizers and pesticides.

The plant species found in different types of biotope vary widely, so these biotope types cannot substitute for each other. The impoverishment through time of cultivated fields is well documented, but the changes in the species composition following intensification of management of permanent grasslands are also indisputable. Additionally, it is unquestionable that the nature value of habitats adjacent to fields in rotation are much affected. However, in the agricultural landscape, the linear and other small biotopes support many more plant species in the field layer than their area alone would suggest (Bunce & Hallam 1993; Marshall & Arnold 1995).

5 Comparison of impact on nature values of the farm types

5.1 Methods

Seven farm types on three different soil types have been defined by the Danish Institute of Agricultural and Fisheries Economics (Schou et al. 1995; Skop & Schou 1996b) in relation to the main production line of the farm and level of economic turnover. The seven farm types are: part-time (abbreviated PT), small and large cattle production farms (CS and CL), small and large plant production farms (PlS and PlL), and small and large pig production farms (PS and PL). The soil types are clay, sand and mixed soil. Each farm type was characterised by size (area), land use, animal stock, and input of pesticide and fertilizer.

In this chapter, the characteristics of the farm types are analysed in relation to differences in their interaction with the nature values. Of interest are both differences between farm types (main production line) and differences between farms on different soil types. The main variables of interest are the size of the farm and possible influences on occurrence of small biotopes; size of areas outside rotation which are potential areas for species rich meadows; areas of special interest for arable wild plants (spring cereals); the potential of the farm type for grazing of grassland areas (stock of grazing animals); and pesticide and nutrient loads on nature values.

Agger & Brandt (1987) have documented that those linear features in the landscape which are property borders are more persistent than those where both sides are owned by the same owner. Assuming that all property borders consist of linear small biotopes, that the shape of a farm is a 2:3 rectangle, and that the total width of a linear small biotope is 4 m (Mean $\pm$ SD = 4.1 $\pm$ 0.38, n=16, unpublished results from Hald et al. 1994), the potential area of a farm occupied by these biotopes has been calculated and are called 'outer linear biotopes'. The labour investment per operation with machinery in the field depends on the size of the field (Nielsen 1989). At a field size <4ha (<8 ha in farms with large machinery) the labour investment is largest, and at field size >15 ha the reduction in labour investment with increasing field size is negligible (Nielsen 1989). Consequently, the size of a physical field is here assumed to be 9 ha. Assuming, that all fields of 9 ha are surrounded by linear small biotopes the area occupied by these between fields has been calculated and are called 'inner linear biotopes'.

The potential of the different farm types for grazing grass areas has been compared through two variables: (i) the total grazing potential, calculated as the number of equivalent dairy cattle including young stock, and based on Scandinavian Feed Units potentially consumed by grazing in the summer season at high utilisation on marginal grassland (Box 3); (ii) the potential stocking rate (here defined as number of potential grazing equivalents per ha), calculated as grazing potential in relation to available area with grass within farm and soil types.

The pesticide loads on nature values from the different farm types has been compared through the average frequency of pesticide treatment, calculated for pesticide use in total, and for use of herbicides, fungicides and insecticides for each combination of farm and soil type. The calculations are based on crop specific treatment coefficients (Statistics Denmark) and land-use of the farm types (Cf. Schou & Skop 1997). Because the size of area outside rotation varies with farm type, and together with set-aside areas is supposed to be totally unsprayed, the treatment frequencies have been adjusted to area within rotation minus set-aside areas. Similarly, application of fertilizer has been calculated from the standard amount needed by different crop types in Denmark independent of soil and climate, i.e. the amount is dependent on the composition of crop types within farm types (Cf. Schou & Skop 1997). In the calculations, application of fertilizer to area outside rotation has been set at zero.

The variables characterising the seven farm types and farms on the three soil types have been analysed by a two-way ANOVA with farm type and soil type as class variable, and followed by a REGW multiple F-test (SAS ver. 6.1 1989). The REGW grouping of the types, X_t (X_1 to maximum X_7 for farm type and X_1 to maximum X_3 for soil type), has been translated into ranks. When transforming the grouping letters into ranks, rank = 1 was given to the group with the lowest nature value, rank=2 to the next group on the nature value scale etc. If a farm type (or soil type) was a member of two or more groups it was allocated a rank = mean of its ranks. The main group of variables analysed by the ANOVA describes the farm and soil types according to area, grazing potentials, pesticide treatment, and fertilizer application (Table 8). The P-values of the ANOVA for soil and farm type are given in Table 8. The maximum and range of each variable and the results from the REGW multiple F-test are given in Table 11.

The results are evaluated in relation to expected impact on nature values.

5.2 Field structure

The total area (A_t) of each farm type did not differ between soil types, but differed among the farm types (Table 8). Within each of the two economic size groups, plant production farms were the largest (Table 9). The total area of each farm types tended to be a multiple of A_t=18 ha, which was the size of a Part-Time farm (Table 9). In the 1950's, the most common farm size among farms larger than 5 ha was 5-10 ha (Fig. 12), which is half the size of a Part-Time farm in the 1990's. Small farms (A_t<= 2) in 1970 occupied 79% of the agricultural area (Fig. 13).

Table 8 P-values of the effect of soil and farm type of the two-way ANOVA analyses of variables characterising the farm types defined by the Danish Institute of Agricultural and Fisheries Economics (Schou et al. 1995; Skop & Schou 1996a). NS: Not significant.

Variable	P-value for Soil type, df=2	P-value for Farm type, df=6
AREA		
Farm total size, ha	0.57 NS	<0.001
Area outside rotation, ha	<0.001	<0.001
Area outside rotation, %	<0.001	0.003
Area with spring barley, %	0.022	0.005
GRAZING POTENTIAL		
Total potential	0.019	< 0.001
Potential outside rotation	0.30 NS	0.0011
Potential within rotation	0.51 NS (df=1)	0.12 NS
PESTICIDE TREATMENT		
Total	0.04	<0.001
Herbicide	0.002	0.097 NS
Insecticide	0.23 NS	0.048
Fungicide	0.042	0.005
FERTILIZER		
Total	0.003	0.009
Manure	0.004	<0.001
Artificial	0.23 NS	<0.001
Leaching	<0.001	0.005
Livestock Units, LU total	0.11 NS	<0.001
Livestock Units, LU per ha	0.48 NS	<0.001

A Part-Time farm with the shape of a 2:3 rectangle has (350m+520m) x 2 x 4 m x 0.5 (the biotope is shared with the neighbour) = 0.35 ha linear biotope at the property border (here called outer biotope). The area of linear small biotopes between the 9 ha physical fields of a Part-Time farm (here called inner biotope) is 520 m x 4 m = 0.21 ha. Assuming that the other farm types are comprised of 'Part-Time-units' the percentage of the more persistent outer linear biotopes decreases with increasing size (A_t) of the farm (Fig. 16). Similarly, the percentage of inner biotopes increases as more of the outer biotopes become more unstable inner biotopes as farm size increases. This means that large farms, and especially large plant production farms, are potentially the greatest threat to linear biotopes because the area of more unstable inner biotopes is largest. In total, from this calculation about 3% of the area is potentially occupied by inner or outer linear small biotopes.

Small area biotopes (marl pits, plantations, ancient monuments etc.) are mostly owned by the same owner, i.e. they are inner biotopes. Therefore, there should theoretically be no differences in their relative numbers, area and stability among farm types.

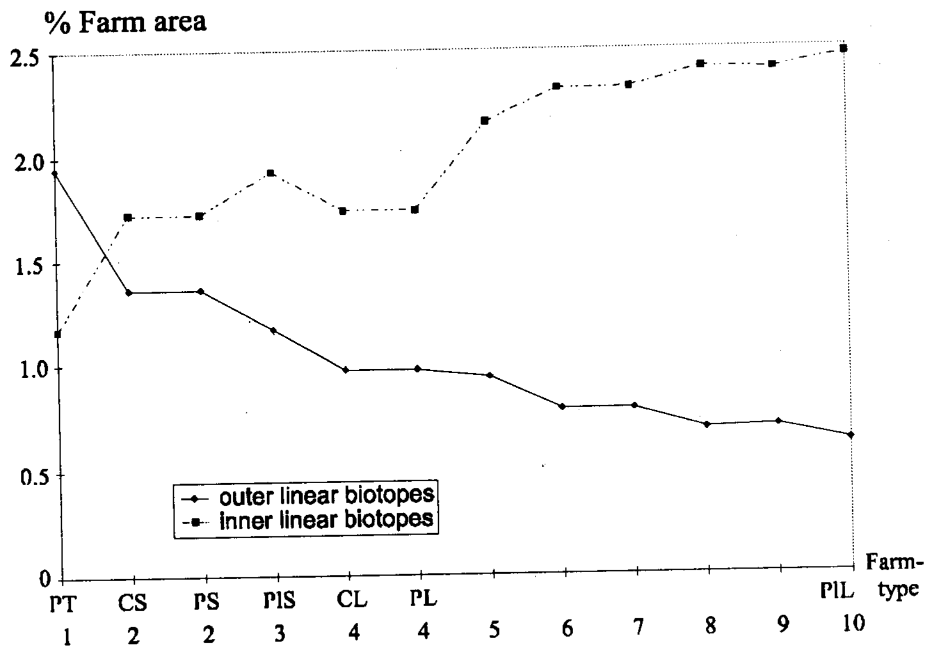


Figure 16 Percentage of farm area (% of total area of the farm) occupied by outer and inner linear small biotopes as function of total farm size (A_t), assuming field-size of 9 ha and width of linear biotopes to be 4 m. A_t=1 is equal to a 18 ha Part-Time farm. Percentage of outer plus inner is constant and equal to 3.1%.

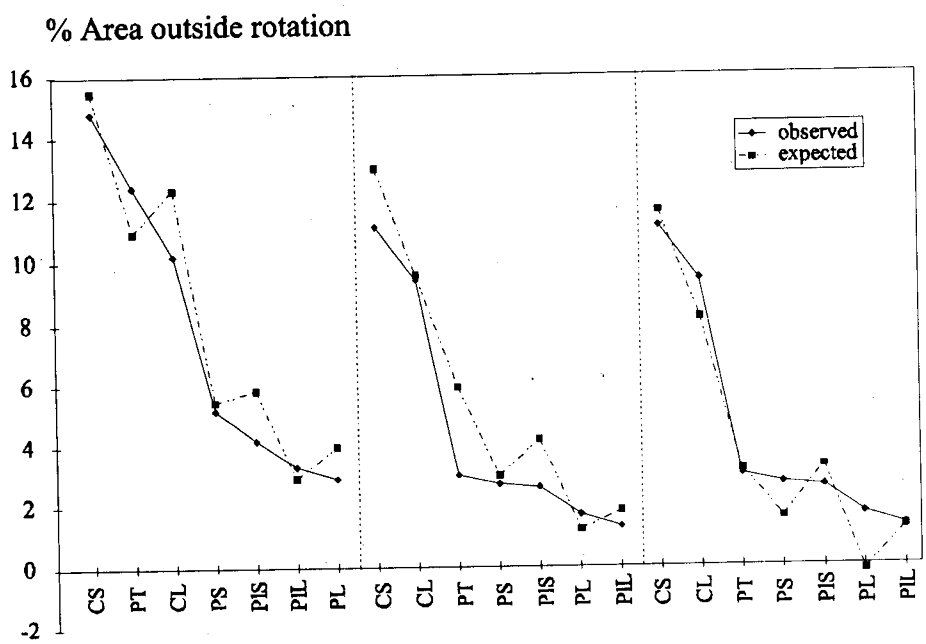


Figure 17 Observed and expected percentage of area outside rotation of the seven farm types on three different soil types (sand, mixed, and clay). Expected has been calculated using A_t, A_o, and effect of soil type from ANOVA (Cf. Table 5). Source: the Danish Institute of Agricultural and Fisheries Economics.

The size of the area outside rotation (A_o) was dependent on both farm and soil type (Table 8). The area outside rotation was largest for cattle production farms regarding both the nominal total area and the relative area of the farm (Table 9). The area outside rotation increased as follows: clay < mixed (1.4 x clay) < sand (2 x clay) within both economic groups. The expected area outside rotation - and thereby potential nature value - was largest for Small Cattle farms on sand (15% of total area) and smallest for Large Pig and Large Plant farms on mixed and clay soil (<2%) (Fig. 17). However, pig and plant production farms do have areas that are marginal in a plant production context. Thus the 'permanent' set-aside area was much higher for pig and plant production farm types than for cattle production farms (Table 10).

5.3 Land use

The percentage area with spring and winter cereals was affected both by soil type and farm type (Table 8). Spring cereals dominated on sand and winter cereals on clay (Fig. 18). Apart from Small and Large Cattle farm types, which have small areas under cereals in general, the area under the two cereal types changed in opposite direction, i.e. spring cereals decreased and winter cereals increased (Fig. 18). Nature value is assumed to increase with the proportion of spring cereals (cf. Chapter 4).

Table 9 Total size (ha, mean over three soil types) of the farm types defined by the Danish Institute of Agricultural and Fisheries Economics (Schou et al. 1995; Skop & Schou 1996a), area outside rotation in ha and percentage (..), and area outside rotation of small and large farms on the three soil types.

A_t and A_o: Size-group classified from total area and area outside rotation, respectively (cf. text). ESE: Economic Size Units.

Farm type Economic size	Part-Time (PT) ha (%)		Plant production (Pl) ha (%)		Cattle production (C) ha (%)		Pig production (P) ha (%)	
Total size								
Small (S) < 80 ESE	18	A_t =1	59	A_t =3	32	A_t =2	34	A_t =2
Large (L) > 80 ESE	-		173	A_t =10	76	A_t =4	74	A_t =4
Area outside rotation								
Small (S) < 80 ESE	1.2 (6.9)	A_o =1	2.1 (3.5)	A_o =2	4.3 (13.1)	A_o =4	1.3 (3.8)	A_o =1
Large (L) > 80 ESE	-		3.5 (2.0)	A_o =3	7.1 (9.2)	A_o =6	1.3 (1.7)	A_o =1

Soil type Economic size	Sand ha	Mixed ha	Clay ha
Area outside rotation			
Small (S) < 80 ESE	3.0	2.1	1.6
Large (L) > 80 ESE	5.6	3.6	2.6

5.4 Grazing potential

The total grazing potential was affected by both soil type and farm type. The grazing potential - and thereby the potential nature value - was highest on sand and lowest on clay. Furthermore, the grazing potential was highest on Large Cattle farms followed by Small Cattle farms (Fig. 19). The other farm types had low grazing potential and did not differ.

The potential stocking rate on grassland outside rotation was affected by farm type only - cattle farms being different from the other farm types (Table 8 and Fig. 19). This means that cattle production farms had a high potential stocking rate. However, the grazing activity on a farm is not expected to take place exclusively on grassland outside rotation as it might be difficult to maintain high milk production.

Therefore, the analysis has been divided in two: dairy cows including young stock grazing on grass areas within rotation (Fig. 19) and the other grazing animals grazing on agriculturally more marginal grasslands outside rotation (Fig. 19). Farm type - but not soil type - did affect the number of potential grazing equivalents per area (Table 8). Farms on clay were extreme with regards to potential stocking rate by dairy animals (including young stock) in relation to grass within rotation having none or very small areas of grass within rotation or of dairy animals. Therefore, a meaningful analysis could not be performed. However, from Fig. 19, it seems probable that Large and Small Cattle farms had higher number of potential grazing equivalents from dairy cattle (including young stock) on grass within rotation than the other farm types. An analysis including sand and mixed soil types only did not show any significant differences between the two soil types. Thus, nature values are assumed to be the same within soil types (Table 11). Small Plant farms had the highest stocking rate with regards to the number of potential grazing equivalents by other grazing animals in relation to area outside rotation.

Table 10 Percentage set-aside (mean from 11 counties + Greater Copenhagen and (SE)) within rotation, outside rotation ('permanent'), set-aside outside rotation plus permanent grassland outside rotation in Danish agriculture in 1994. The agricultural land was divided into two groups: I. Animal husbandry farms excluding pig farms, and II. Plant production farms including pig farms. P-value of paired t-test of the two groups of farming lines. Source: Statistics Denmark.

Land use types Farming group	Total area 1,000 ha	% set-aside within rotation Mean (SE)	% set-aside outside rotation Mean (SE)	% set-aside outside + % permanent grass-land Mean (SE)
Animal husbandry	1,733	3.2 (1.1)	2.5 (0.12)	13.2 (1.1)
Plant and Pig production	958	3.0 (0.16)	5.8 (0.35)	10.7 (0.88)
P-value of paired t-test		0.36	<0.0001	0.02

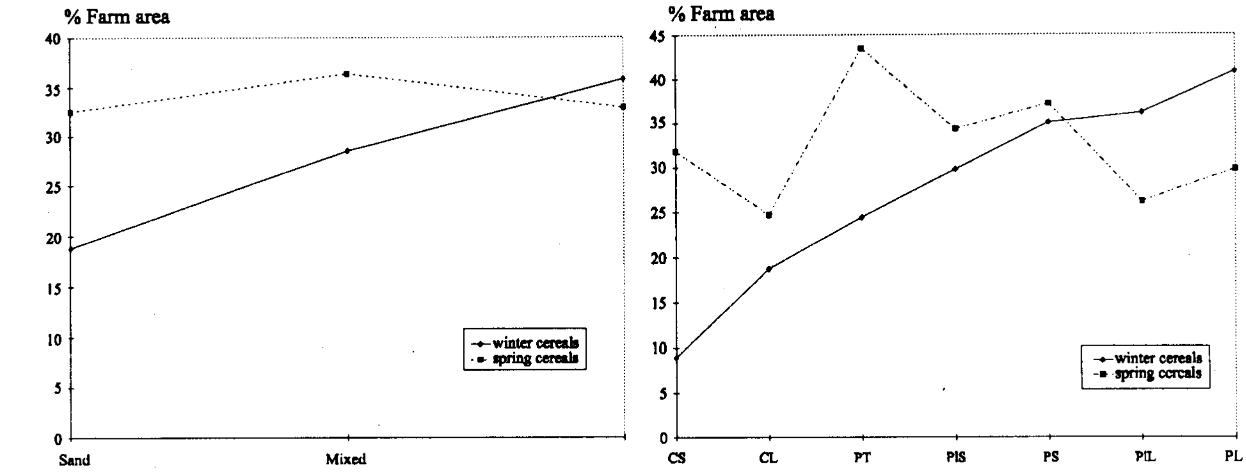


Figure 18 Percentage of farm area with winter and spring cereals respectively, in relation to soil type (Left) and farm type (Right). Source: the Danish Institute of Agricultural and Fisheries Economics.

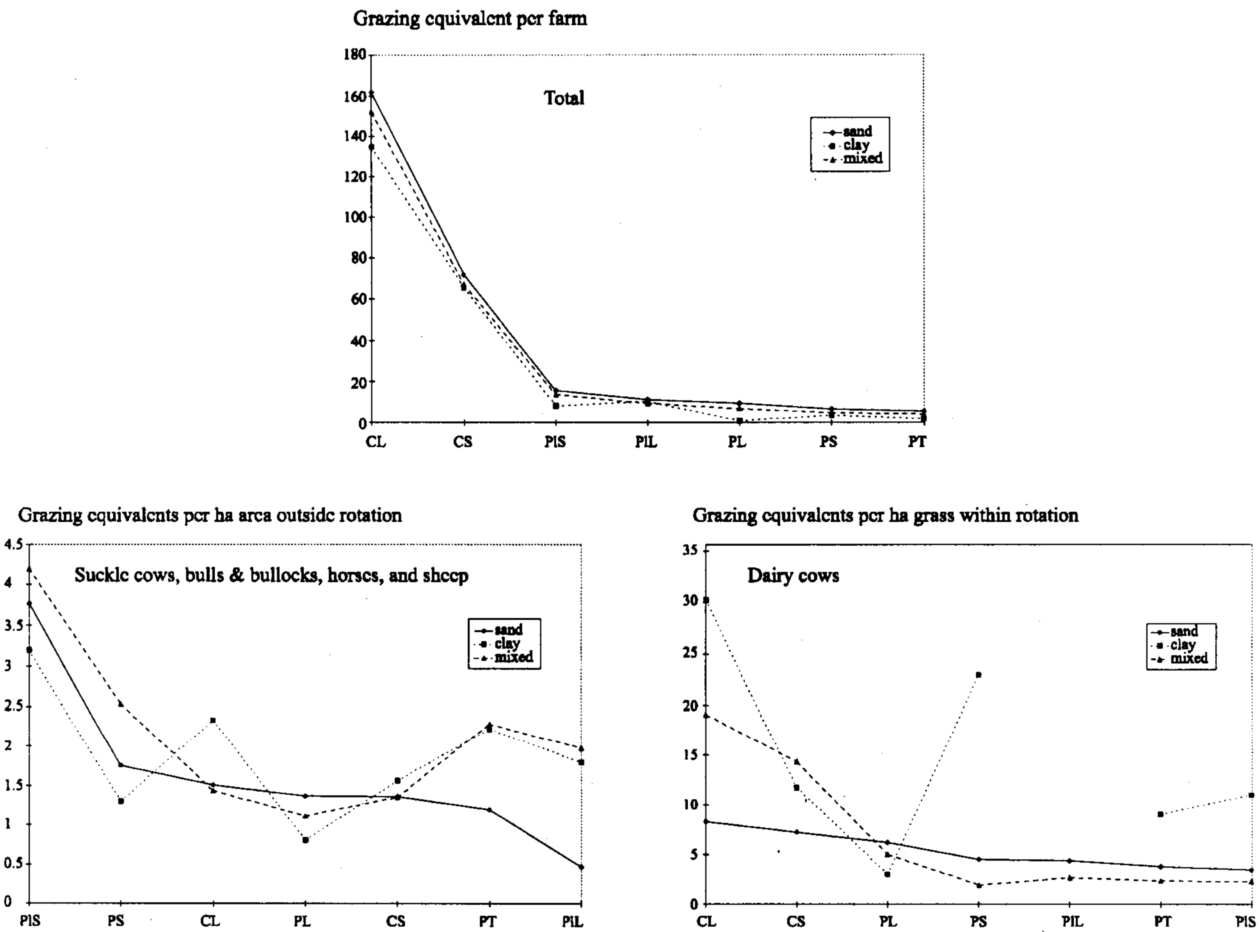


Figure 19 Calculated grazing potential per ha (cf. Box 3) in relation to farm and soil type. A. Total grazing potential B. Dairy cows including young stock on grass within rotation C. Suckle cows including calves, bulls & bullocks, horses, and sheep on grassland outside rotation. Source: the Danish Institute of Agricultural and Fisheries Economics.

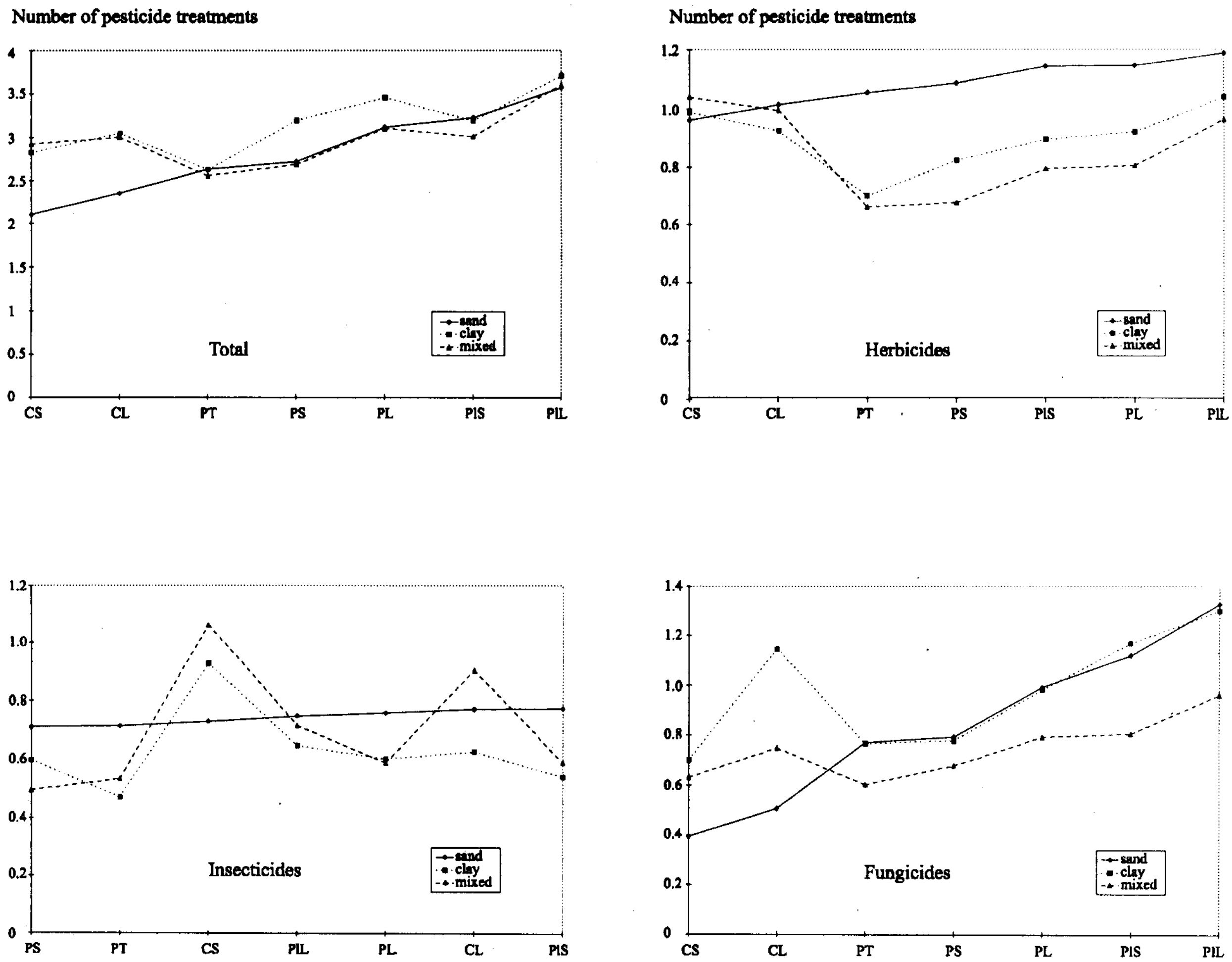


Figure 20 Mean number of pesticide treatments (# per ha area within rotation) (calculated from the composition of the crops) in relation to farm and soil type. A. Total pesticide application. B. Herbicide. C. Insecticide. D. Fungicide. Source: the Danish Institute of Agricultural and Fisheries Economics.

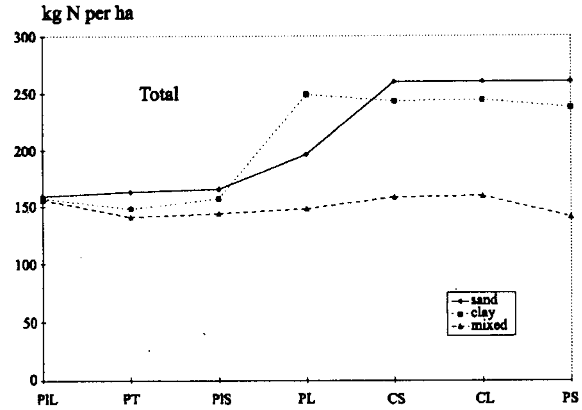
As both too high and too low grazing pressure may be deleterious for the performance of a species rich grassland vegetation (Huston 1994; Hald 1995), the nature value has been assumed to be highest when the grazing stock rate was close to two and six grazing equivalents for grassland outside rotation and grass within rotation, respectively.

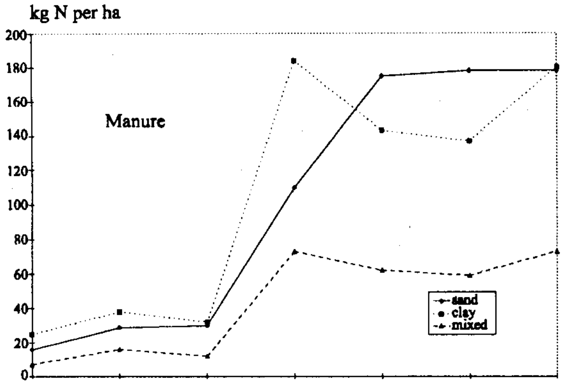
5.5 Pesticides

Frequency of total pesticide treatment and of fungicide treatment were both affected by soil and farm type (Table 8). In both cases, Large Plant farms on clay had the highest treatment frequency (Fig. 20). This corresponds to the higher share of winter cereals on these farm types. Frequency of treatment with herbicide was affected by soil type only (Table 8), and was highest on sand, possibly an effect from the areas with potatoes, which primarily are cropped on sandy soil. Treatment with insecticide was affected by farm type only (Table 8), and cattle production farms had the highest treatment frequency, possibly an effect from the areas with fodder beet, which had a treatment coefficient of 2.53 for insecticides, and are mainly grown by cattle production farms (Schou & Skop 1997). In evaluating the nature value, low frequency of pesticide treatment was assumed to have the highest nature value (cf. Chapter 4).

Table 11 Rank of nature values of soil and farm types within four main variable groups, based on the results presented in tables and figures (cf. Source column 1). Statistical results are presented in Table 8. Rank 1, 2, 3 ... 7 has been given according to the multiple F-test (ANOVA). Rank =1 for low nature value. Rank Sum = [3; 6] and [7; 28] for soil type and farm type, respectively. Ratio: Ratio between maximum and minimum value of the variable.

		SOIL TYPE						FARM TYPE											
Source Tables & Figures	Variable	Sand	Mixed	Clay	Rank Sum *Mean*	Maximum value	Ratio of values	PT	PIS	PIL	CS	CL	PS	PL	Rank Sum *Mean*	Ranks Range	Maximum value	Ratio of values	Comments on nature values
		Rank						Rank											
AREA																			
Tab. 9	Total farm size, ha	1.0	1.0	1.0	3.0	65.0	1.0	5.0	3.0	1.0	4.0	2.0	4.0	2.0	21.0	1-5	18.0	9.5	Decrease with size
Tab. 9	Area outside rotation, ha	2.0	1.0	1.0	4.0	4.1	2.0	1.0	1.5	2.5	3.0	4.0	1.0	1.0	14.0	1-4	7.1	5.7	Increase with ha area outside rotation
Tab. 9	Area outside rotation, %	2.0	1.0	1.0	4.0	7.6	1.8	2.5	1.5	1.0	4.0	3.0	1.5	1.0	14.5		13.1	7.5	Increase with % area outside rotation
Fig. 18	Area with spring barley, %	2.0	1.5	1.0	4.5	36.0	1.3	2.0	1.5	1.0	1.5	1.0	1.5	1.0	9.5	1-2	43.0	1.8	Increase with % area with spring barley
	Total rank	7.0	4.5	4.0	***3.8***	112.7	6.1	10.5	7.5	5.5	12.5	10.0	8.0	5.0	***14.8***				
GRAZING POTENTIAL																			
Fig. 19	Potential, total	2.0	1.5	1.0	4.5	40.0	1.3	1.0	1.0	1.0	2.0	3.0	1.0	1.0	10.0	1-3	149.0	39.0	Increase with grazing potential
Fig. 19	Potential outside rotation (bull & bullocks, sheep, horses, suckle cows)	1.0	1.0	1.0	3.0	2.1*	1.3	2.0	1.0	2.0	2.0	2.0	2.0	2.0	13.0	1-2	1.9*	3.4	Decrease with increasing discrepancy from 2.0
Fig. 19	Potential within rotation minus clay (dairy cattle incl. young stock)	1.0	1.0	*1.0*	3.0	5.4*	1.3	1.0	1.0	1.0	1.0	1.0	1.0	1.0	7.0	1	5.6*	4.8	Decrease with increasing discrepancy from 6.0
	Total rank	4.0	3.5	3.0	***3.5***			4.0	3.0	4.0	5.0	6.0	4.0	4.0	***10.0***				
PESTICIDE TREATMENT																			
Fig. 20	Total	2.0	1.5	1.0	4.5	2.8	1.1	3.0	2.0	1.0	3.0	2.5	2.5	1.5	15.5	1-3	2.6	1.4	Increase with decreasing pesticide load
Fig. 20	Herbicide	1.0	2.0	2.0	5.0	0.9	1.3	1.0	1.0	1.0	1.0	1.0	1.0	1.0	7.0	1	0.8	1.3	Increase with decreasing herbicide load
Fig. 20	Insecticide	1.0	1.0	1.0	3.0	0.6	1.2	2.0	1.5	1.5	1.0	1.5	1.5	1.5	10.5	1-2	0.6	1.6	Increase with decreasing insecticide load
Fig. 20	Fungicide	1.5	2.0	1.0	4.5	0.8	1.3	2.5	1.5	1.0	3.0	2.0	2.5	2.0	14.5	1-3	0.6	2.1	Increase with decreasing fungicide load
	Total rank	5.5	6.5	5.0	***4.3***			8.5	6.0	4.5	8.0	7.0	7.5	6.0	***11.9***				
FERTILIZER																			
Fig. 21	Total	1.0	2.0	1.0	4.0	159.0	1.4	2.5	3.0	3.0	1.0	1.5	2.0	2.0	15.0	1-3	161.0	1.6	Increase with decreasing total fertilizer load
Fig. 21	Manure	1.0	2.0	1.0	4.0	46.0	2.4	2.0	2.0	2.0	1.0	1.0	1.0	1.0	10.0	1-2	16.0	9.1	Increase with decreasing manure load
Fig. 21	Artificial	1.0	1.0	1.0	3.0	104.0	1.1	2.0	1.5	1.0	2.5	3.0	4.0	4.0	18.0	1-4	72.0	2.0	Increase with decreasing artificial fertilizer load
	Leaching	1.0	1.5	2.0	4.6	63.0	1.4	3.0	3.5	4.0	2.0	2.5	1.0	1.5	17.5	1-4	53.0	1.9	Increase with decreasing leaching load
	Livestock Units, total	1.0	1.0	1.0	3.0	63.0	1.1	6.5	6.5	5.0	4.0	1.0	3.0	1.0	27.0	1-6.5	160	27.1	Increasing with decreasing LU
	Livestock Units, per ha	1.0	1.0	1.0	3.0	1.1	1.1	6.0	6.0	6.0	3.5	3.5	2.0	1.0	28.0	1-6	2.16	12.0	Increasing with decreasing LU
	Total rank	6.0	8.5	7.0	***3.6***			9.5	10.0	10.0	6.5	8.0	8.0	8.5	***15.1***				
Mean ranks of 4 main groups		1.36	1.33	1.10	*3.8*			2.44	2.03	1.83	2.28	2.08	1.84	1.46	***14.0***				
Rank of SOIL and FARM TYPE		a	b	c				a	d	f	b	c	e	g					





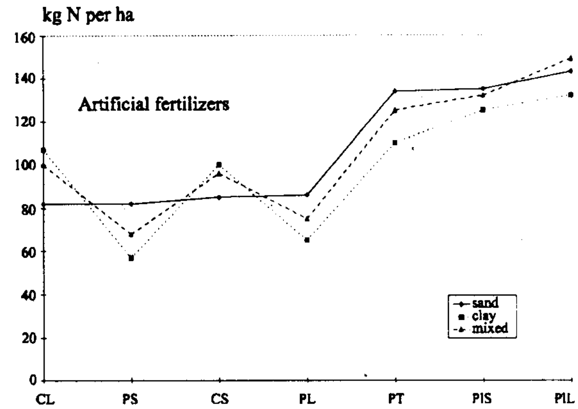


Figure 21 Fertilizer application (kg N per ha total area) in relation to farm type and soil A. Total application. B. Manure. C. Artificial fertilizer. Source: the Danish Institute of Agricultural and Fisheries Economics.

5.6 Fertilizers

Cattle and pig production farms applied the highest total amount of fertilizer (Fig. 21). The total amount was also affected by soil type (Table 8), highest on sand and clay. A similar effect of soil type was found in the application of manure, while application of artificial fertilizer was affected by farm type only (Table 8). As expected, plant production farms applied most artificial fertilizers, while cattle and pig production farms applied most manure. Leaching could only be calculated for sand and clay soil types (Skop & Schou Submitted). The leached amount per ha within rotation was highest for pig production farms on sandy soil.

The amount of fertilizer applied and drifting - more than the amount leached - has an effect on terrestrial nature values in the fields in rotation and their surroundings. However, plant communities in terrestrial wetlands such as spring mires and wet meadows are also affected by N and P content in the water leaching from the fields. The amount of nutrients drifting into the areas adjacent to the fields such as the small biotopes (Kleijn 1996) can easily be reduced when the nutrients are applied using a screen. Drift from manure in fields originates both from solids and from evaporated NH_3, and, therefore, is less easy to control. Thus to avoid manure deposits outside the cultivated fields, distance is the only solution. Evaporation of NH_3 from fields is reduced by burying or rapid incorporation of the manure into the soil. Ammonia also evaporates from stall and storage. The Livestock Unit (LU) is used as a proxy of the size of this evaporation. The LU differed among farm types but was not affected by soil type (Table 8). Evaporation and dry deposition of NH_3 from stall and storage of Large Pig farms is considered in Chapter 6. In evaluating the nature value, low fertilizer application and low LU was assumed to have the highest nature value (cf. Chapter 4).

5.7 Discussion and conclusion

The impact of farm type is categorised according to four main variables: Area, Grazing, Pesticide and Fertilizer. A potential of 3% of the agriculturally managed area of a farm occupied by linear small biotopes is a realistic goal of sustainable agriculture. Thus, Larsen & Clausen (1995) in a survey of organic farms in Eastern Denmark (Zealand) found the linear small biotope to occupy 3.1 % of the farm area. In the same survey, they found 3.5% of the farm area occupied by small area biotopes (<2ha). Brandt (1994) in 32 survey areas each of 4 km^2 (at least two thirds agricultural land) found that linear and small area biotopes together typically occupied 2-3 % of the total survey area. Assuming two thirds of the total area is agricultural land, the adjusted percentage based on agricultural land alone is 3-4%. The variable Pesticide had the highest mean score among soil types and, therefore, differentiated most between soil types (Table 11). Similarly, Fertilizer and Area differentiated most between farm types. Also the main variable, Grazing, differed among farm types. Thus the variable Grazing separated the farm types into two or three clearly separate groups, and showed a high ratio between the maximum and the minimum value of the variables. Comparing the influence of soil and farm types on nature values, differences in farm type had the highest influence (the highest mean score in relation to minimum possible score of three for soil type and seven for farm type; the highest ratio between maximum and minimum of the variables (Table 11); and the highest number of significant effects (Table 8).

The ranks given to farms are based on assumptions about the influences of the different variables (cf. Table 11) on nature values. The assumptions are in agreement with the results and discussions given in preceding chapters of this report. Giving equal weight to the four main variables presented in Table 11, farms on clay had the lowest score, and thereby the lowest expected nature values. According to farm types the rank order was PT, CS > CL, PlS > PS, PlL > PL giving highest nature value to Part-Time, cattle production and Small Plant farms and lowest to pig production farms and Large Plant farms. It must be mentioned that this ranking was obtained despite the fact that cattle production farms within the main variable, Fertilizer, had the lowest score. Combining soil and farm types, farms with cattle production on sand or mixed soils had the highest potential nature value, while large plant and pig production farms on clay had the lowest nature value (Table 11).

6 Effect of current location of the farm types on nature values

6.1 Methods

The geographic location of farms (i.e. point location of farm house) in Vejle County is known from Anonymous (1995). From this source, Skop & Schou (1996a; 1996b) have assigned all the farms including areas belonging to the farms (polygons) in Vejle County to a farm type in accordance with the definition of farm types by the Danish Institute of Agricultural and Fisheries Economics, and which is used in this report (cf. Fig. 3 in Skop & Schou 1996b). The geographical location of all §3 protected natural areas is delivered fromVejle County (cf. Fig. 4). To evaluate the potential influence of farm types on local natural areas concerning grazing opportunities and local pollution with ammonia, the two sets of location data have been compared. Furthermore, as the physiotope map might be used in relation to restoration of natural areas (Lenz & Stary 1995), pollution with ammonia has been compared with the physiotope map. The location of different farm types in relation to potential for grasslands on low-lying land has also been investigated. This might be of interest in relation to the protection of aquatic natural areas and because the actual area of grassland outside rotation is very small for farm types other than cattle and Part-Time farms, especially on clay soil (cf. Chapter 5).

The GIS analysis used in the evaluation of the interaction between location of farms and types of natural areas has been done by Bernd Münier in ArcView ver. 3.0. The different types of natural areas were converted to pixels of 25m x 25m and the farms represented by a point, which was the farm house. Calculations of the Euclidean Distance from a pixel (natural area) to the nearest point (farm) has been made by the 'Find distance' command. In calculating the potential area of meadows on low-lying lands belonging to each farm type, the location of oligotrophic and eutrophic meadow physiotopes (Münier & Christensen 1996) has been compared with the location of

Table 12 Mean distance (m) from natural areas protected by §3 of the Protection of Nature Act to farms with high grazing (Cattle and Part-Time farms) and low grazing potential (Pig farms) in Vejle County.

Calculated mean and (standard deviation) of distance from different types of natural areas to the nearest farm (location of farmhouse) of Cattle farms (CS and CL) and Large Pig farms (PL). The distance has been calculated for each 25m x 25m pixel of each types of natural areas. Source: Anonymous 1995 (location of farms) and Vejle County (§3 natural areas). Calculations by Bernd Münier by ArcView command 'Find distance'

	Number of pixels 1 pixel = 625 m^2	Euclidean Distance (m) from §3 natural area to						
Farm type (abbreviation)		Cattle (CS + CL)			Part-Time (PT)		Large Pig (PL)	
§3 natural area	10^3 x n	Mean	(SD)	Median	Mean	(SD)	Mean	(SD)
Dry grassland	36	1,199	(889)	1,002	491	(332)	2,613	(1,631)
Meadow	99	1,308	(903)	1,100	541	(292)	2,612	(1,913)
Fen	93	1,433	(870)	1,261	702	(564)	2,836	(1,572)
Heath	46	1,999	(1005)	1,840	1,161	(677)	3,199	(1,345)
Salt meadow	4.9	2,140	(1738)	1,534	804	(493)	5,010	(2,642)

the polygons of farm types (Skop & Schou 1996b). Calculations of dry deposition of NH_3 in four directions at different distances from a Large Pig farm was done by Willem Asman by means of his model 'nh3point'. It was assumed, that the number of pigs was 1,500 (corresponding to Large Pig farms), and the emission from stall and storage only was included in the calculations. The 'nh3point' model is base on results presented by Asman (1997).

6.2 Grazing opportunities

The pixels of all types of semi-natural areas were on average located closer to Part-Time farms than to cattle farms, and closer to cattle farms than to Large Pig farms (Table 12).

Pixels of dry grasslands, meadows and fens were in general located closer to farm houses than pixels of heath and salt meadow (cf. Fig. 22). This supports the difference in grazing tradition often found for dry grassland and meadow compared to salt meadow. While salt meadows often are grazed by animals from several farms far away, dry grasslands and meadows are more often grazed by the local farmers. However, from the size of the mean (and median) distance from a pixel of grazing dependent semi-natulal areas (dry grassland and meadow) to a farm with grazing animals, i.e. cattle farms and Part-Time farms, it follows that in practice Part-Time farms are more likely to graze these marginally located areas than cattle farms (Table 12). However, a mean distance of 1,000 m to the nearest cattle farm means that on average a circular area of 314 ha around a pixel of semi-natural area does not contain a cattle farm. This is very high compared to the mean size of Large Cattle farms which is 76 ha. Therefore, it is interesting to know what proportion of the area of a certain types of semi-natural areas is located within farms when the simulated farm size is 18 ha, 32 ha, and 76 ha (corresponding to the size of Part-Time, Small Cattle farms, and Large Cattle farms, respectively Table 13, cf. Table 9). Although Part-Time farms are the smallest of the three farm types compared in Table 13, they do include much larger areas of each type of semi-natural areas than either Small or Large Cattle farms, except heath (Table 13).

6.3 Potential of grasslands on low-lying land

The area of the two physiotopes, oligotrophic and eutrophic meadows, has been compared for different farm types in a section of Vejle County (cf Fig. 3) to evaluate the future opportunities of taking low-lying lands out of rotation for environmental purposes.

Figure 22 (page 91) Location of cattle production farms (CS and CL) and grazing dependent §3 natural areas and §3 heath in Vejle County. Circular zones of potential influence from each farm are depicted for r = n x 500m. Source: Anonymous (1995) and Vejle County (§3 natural areas). GIS is by Bernd Münier.

Table 13 Percentage of different §3 natural areas located within a defined area around farm types with high grazing potential (Part-Time (PT) and Cattle farms) in Vejle County.

The number of pixels of the different types of natural areas within a circular area around the farm type is calculated for Part-Time farms, and for small (CS) and large cattle (CL) farms together. Radius of 239 m, 319 m, and 492 m correspond to farms of 18 ha, 32 ha, and 76 ha respectively which is the size of farm types PT, CS, and CL (cf. Table 9).

Source: Anonymous (1995) (location of farms) and Vejle County (§3 natural areas). Calculations by Bernd Münier by ArcView command 'Find distance'.

	Number of pixels 1 pixel = 625 m^2	Percentage of pixels of each natural area located within a defined area around a farm type		
Farm type (abbreviation) **Radius**		Part-Time (PT) r $\leq$ 239 m	Cattle (CS + CL) r $\leq$ 319 m	Cattle (CS + CL) r $\leq$ 492 m
§3 natural area	**Number x 10^3**	%	%	%
Dry grassland	36	18.6	6.3	10.4
Meadow	99	12.8	4.0	11.3
Fen	93	9.1	2.2	7.8
Heath	46	2.6	0.8	3.0
Salt meadow	4.9	3.9	0.4	1.4
% of total area occupied by the defined farm area		27 %	23 %	55 %

For example, permanent grasslands along rivers may protect water courses against soil erosion in areas with steep slopes and also increase denitrification of water leaching from fields to the water courses, thereby benefiting the quality of the water.

Plant and pig production farms are in general located on areas with the lowest potential for grasslands on low-lying lands (Table 14). Cattle farms and Part-Time farms both have the largest potentials for grasslands on low-lying land and actually also have the largest area of grassland outside rotation (Table 14).

The rank of farm types regarding the potential for meadows on low-lying land and areas of grasslands outside rotation is the same except for Large Pig farms (Table 14). While cattle production farms had more grassland outside rotation than the potential for low-lying land, plant production farms and Large Pig farms had less grassland outside rotation than the available potential of low-lying lands. The large potential of plant and pig production farms for establishing grassland outside rotation is in agreement with the larger interest of these farms than of cattle farms for setting-aside outside rotation (cf. Table 10).

6.4 Local pollution with ammonia

Some types of natural areas, for example heath, bogs and other oligotrophic types, are more sensitive to nutrient load than others. The critical nitrogen (N) load of heath is equal to the present day mean background deposition in Denmark, 15-25 kg N ha^{-1} year^{-1} (Grennfelt & Thörnelöf 1992; Riis-Nielsen 1996). The critical load of bogs is much lower, $\leq$ 5 kg N ha^{-1} year^{-1}, which is equal to the background deposition in the 1950's-1960's (Risager 1996). Therefore,

Table 14 Grassland outside rotation compared with potentials for meadows on low-lying land within farm type. Grassland outside rotation includes grassland on both upland and low-lying land. Potential for meadows is the sum of oligotrophic and eutrophic meadow physiotopes on low-lying land within the area allocated to different farm types in a section of Vejle County (Fig. 3) in percentage of the total area allocated to the respective farm types within the same section. Source: The Danish Institute of Agricultural and Fisheries Economics (SJFI) (grassland outside rotation cf. Table 9); Anonymous (1995) and Skop & Schou (1996a, 1996b) (location of areas of farm types); Münier & Christensen (1996) (physiotope map). Calculation of potential meadow areas by Bernd Münier by ArcView.

Farm type	Small Cattle CS	Large Cattle CL	Part-Time PT	Small Pig PS	Small Plant PlS	Large Plant PlL	Large Pig PL
Grassland outside rotation (on upland and low-lying land), % (SJFI statistics)	13.1	9.2	6.9	3.8	3.5	2.0	1.7
Potential meadow (on low-lying land), % (Section of Vejle County)	4.3	3.8	3.5	3.3	3.0	3.0	3.1
Difference	8.8	5.4	3.4	0.5	- 0.5	- 1.0	- 1.4

an extra amount of 5 kg N ha^{-1} $year^{-1}$ from a local source is expected to have a great impact on natural areas. However, as the critical N load of heath and other types of natural areas has already been exceeded by the background deposition of N (Risager 1996) the distance of zero N load from a local source is of interest.

The interactions between agriculture and various types of natural areas are two-way. Farms with animals produce manure which may be a threat to natural areas through nutrient load, but farms with cattle also have the opportunity to graze the grazing dependent semi-natural areas to compensate for this extra nutrient load. Pig farms produce manure only. Typically, Large Pig farms are located at a distance of 3 km from heath (Table 12). Although the distance from heath pixels to pig farms as a mean is larger than the distance to cattle farms (Table 12), Large Pig farms in Vejle County seem not to avoid heath areas on purpose (Fig. 23).

The calculated dry deposition of N at different distances from stall and storage of a Large Pig farm is larger than 5 kg N ha^{-1} $year^{-1}$ up to a distance of 300 m from the farm, and close to (statistical) zero at a distance of 600 m (Fig. 24). In total, 100 ha of dry oligotrophic types of natural areas (dry grassland and heath) is situated within a radius of 600 m from Large Pig farms in Vejle County (Table 15). In relation to the relative area of the §3 natural areas in Vejle County (Table 15), heath areas are influenced less than other types by Large Pig farms.

Figure 23: (Page 93) Location of large pig production farms (PL) and §3 heath areas in Vejle County. Heath areas are sensitive to nutrient load, for example NH_3 deposition. Circular zones of potential influence from each farm are depicted for r = 500m, 1000m, and 1500m. No influence distance is 600-1000m (cf. Fig. 24). Source: Anonymous (1995) and Vejle County (§3 heath areas). GIS is by Bernd Münier.

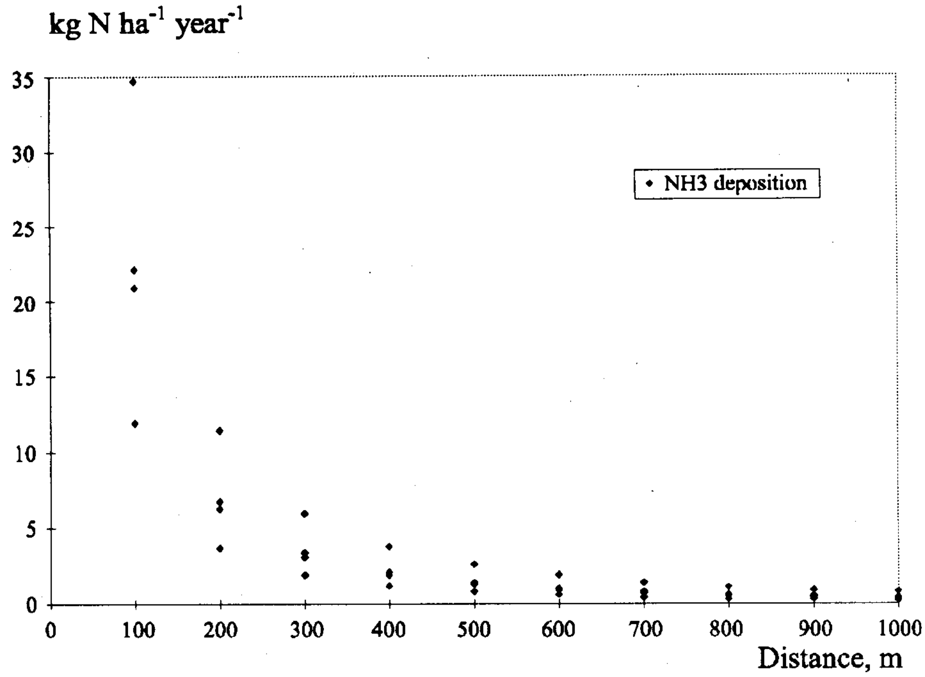


Figure 24 Dry NH_3 deposition (kg N ha^{-1} $year^{-1}$) at different distances (m) from a large pig farm (1,500 pigs). NH_3 emission is from stable and storage only, and calculation of deposition is made by model nh3point by Willem Asman. Model nh3point is based on results in Asman (1997).

The reason could be that the heaths are larger than the other types of natural areas and therefore have a better protected centre area. As the area within a radius of 600 m is far beyond the size of Large Pig farms (76 ha ~ r=485m, Table 9), areas outside the farm are also affected. Today, the areas left with dry grassland and heath in Vejle County are small. The quality of most of these areas is unknown, but will decrease in response to the extra ammonia load.

Today, regeneration of natural areas is a popular topic. Potential areas for this may be found on the physiotope map - especially potential oligotrophic areas should be among the best candidates. Nine to ten percent of the area of each physiotope type is within a radius of 600 m from a Large Pig farm, except wet heath and oligotrophic meadows which have a lower percentage (Table 15). In locating new pig farms, potentially oligotrophic natural areas should be taken into consideration to minimise the influence on these areas, so that the possibility of future regeneration of these types of natural areas is not reduced or totally lost.

Table 15 §3 natural area in Vejle County and physiotope types (section of Vejle County only) affected by dry deposition of NH_3 from Large Pig farms (PL). The affected area has been calculated both as ha and as % of the total area of the type within Vejle County (§3 natural area) and within the section of Vejle County (physiotopes).

Assuming a stock of 1,500 pigs, the deposition of NH_3 as a function of distance from the pig farm has been calculated for four directions (Fig. 24). NH_3 emission is from stall and storage only.

Source: Vejle County (§3 natural area). Calculations of NH_3 deposition is made by Willem Asman with model nh3point, which is based on the results presented by Asman (1997). Calculation of affected area by Bernd Münier by ArcView.

§3 natural area Vejle County as a whole	Area and (%) of §3 natural area within		**Physiotope types** Cut of Vejle County, cf. Fig. 3.		Area and (%) of physiotope within	
	300 m	600 m	Radius of buffer zone		300 m	600 m
	≥ 6.0	≥ 1.9	Calculated maximum deposition of NH_3 kg ha^{-1} $year^{-1}$		≥ 6.0	≥ 1.9
	ha	ha (%)			ha	ha (%)
Dry grassland	9	91 (4.0)	Oligotrophic	Dry grassland	1954	7271 (9.2)
Heath	0	9 (0.3)		Heath	455	1754 (9.6)
				Wet heath	3	20 (2.3)
				Meadow	5	28 (6.5)
Meadow	36	195 (3.2)	Eutrohpic	Meadow	90	317 (9.6)
Fen	24	141 (2.4)		Fen	54	347 (9.2)

6.5 Discussion and conclusion

As cattle farms, in general, are located far from semi-natural areas in need of grazing, a special effort has to be made to attract grazing to these areas. Part-Time farms are closer to grazing dependent semi-natural areas than other farm types with high grazing potential. Therefore, a sustainable farming system in the agricultural landscape should encourage farmers with cattle and farmers who do not graze their own semi-naturural areas to find new ways to ensure that the grazing dependent semi-natural areas are grazed in the future.

The location of the different farm types in Vejle County shows that all farm types have a potential of at least 3 % of grassland outside rotation on low-lying lands. Plant and pig production farms in particular have small areas of grassland outside rotation in comparison with the potentially available area. Among farm types, the area of grassland outside rotation was least on clay (cf. Table 11). This potential for grassland outside rotation could be utilised to benefit the environment. Although leaching of nitrate on clay soil is lower than on sandy soil, leaching from clay soil is to a high degree through drainage water which flows only a short distance before reaching the water course (Skop & Loaiciga Submitted). This means that the opportunities for denitrification before the water reaches the water course could be increased through establishing permanent grasslands along water courses to filter the drainage water.

The location of pig farms in Vejle County shows that they do impact §3 natural areas, and probably also on areas that do not belong to the pig farms themselves. Furthermore, they affect areas potential for oligotrophic types of natural areas. A sustainable agricultural system must take account of the whole landscape. This should be implemented in connection with location of pig farms - and other farm types - so that farms do not interfere with future possibilities of establishing oligotrophic types of natural areas. No farm should, therefore, be located or have such a size as to affect local §3 natural areas or areas of potential oligotrophic/mesotrophic types of natural areas with ammonia deposition.

The conclusions drawn from the location of farm types and their relationship to local types of natural areas confirm the conclusions drawn in Chapter 5, giving higher nature value to Part-Time than Small Cattle farm. In rank, the Part-Time farm is followed by cattle production and Small Plant farm types and lowest rank is given to pig production farms and Large Plant farms (PT > CS > CL, PlS > PS, PlL > PL).

7 Sustainable agriculture and nature values

7.1 Introduction and methods

Farmers manage the main part of our grasslands outside rotation as well as small biotopes between fields, and the fields within rotation. These areas are directly linked to farming practice, and, therefore, farmers hold the key to the development of the nature values of these areas in the future. Furthermore, farming practice has a more or less indirect influence on the other types of natural areas like. Therefore, sustainable agriculture must be evaluated in terms of the whole agricultural landscape including the direct influence on grassland outside rotation, small biotopes between fields, and the fields within rotation and the indirect influence on other natural areas. However, some farm types potentially contribute with higher nature values and less negative impact than others. As shown in the preceding chapters, farms with cattle production on sand or mixed soils have the highest potential nature value, while Large Plant and Large Pig farms on clay have the lowest nature value. Among farm types with high grazing potential, Part-Time farms are located closest to grazing dependent semi-natural areas, and therefore have the greatest potential for nature management by grazing in the future. Not only potentially but also in the real world do different farm types contribute differently to nature values. Thus Potter et al. (1996) linked the UK Countryside Survey of environmental stock (deciduous woodland, semi-natural vegetation, and extensively grazed grasslands) and a Farm Survey to identify relationships between farm types and environmental stock. They found that environmental stock was highest among 'livestock farm' types and lowest among 'arable farm' types.

A comparison of the changes that have taken place in Danish agriculture 1955-1995 (cf. Chapter 3) with the trend in nature values (cf. Chapter 4) shows that the changes in agriculture have been accompanied by a decrease in nature values. The trends in agricultural change are expected to continue in the future (Stryg 1994). Thus, the expected effects of the 1992 General Agreement on Tariffs and Trade (GATT) are increasing size of farms and number of pigs, and decreasing areas with cereals and permanent grassland, and decreasing grazing equivalents. Therefore, it is high time to intervene, if the agricultural landscape is to contain nature values other than those left over by pig and plant production farms. A political decision on how to maintain a certain minimum level of nature values in the agricultural landscape, i.e. baseline nature values, has to be taken, as proposed by Hald (1992). Furthermore, measures to protect and manage grazing dependent semi-natural areas in the future are urgently needed, as well as to protect other high quality natural areas.

As the different farm types potentially exert different impacts on nature values, the *a priori* needs to regulate at the farm level are greater for Large Pig and Large Plant production farms on clay than the other farm types. The low expected nature values of Large Pig and Large Plant farms are mostly caused by differences in size of the farm (less small biotopes), land use (less proportion of area outside rotation, less spring sown cereals), less grazing potential, and more pesticide application. In the following it is assumed that the farmers' contribution to nature values of the country in the future should be independent of farm type, size and soil. This assumption is in accordance with the sustainable landscape approach (Barrett 1992). Also, it is assumed that the nature values of each variable should always be close to the best example of the different farm types (cf. Table 11).

In this chapter, effects on nature values are evaluated by two methods: (i) changes caused indirectly from a per-unit tax on nitrogen on variables that are important for nature values, i.e. land use, livestock, pesticide treatment frequency, fertilizer treatment, and leaching; (ii) direct changes in nature values through requirements on the quantity of natural areas and rewards for biotope quality of the different areas.

The first method is based on scenarios made by Schou & Skop (1997). They made two policy scenario analyses using statistics of the seven different farm types on sand and clay (cf. Chapter 5) and integration of two models: the Integrated Spatial Modelling Framework (ISMF) and an econometric model of the Danish agricultural sector (ESMERALDA). The two scenarios analysed were: (I) a per-unit tax on nitrogen in artificial fertilizers corresponding to 100% of the price of the nitrogen. (II) a per-unit tax on nitrogen in artificial fertilizers and animal feed-stuff imported by the sector corresponding to 100% of the price in artificial fertilizers. In both scenarios it was assumed that farm structure including farm size was unchanged, and that the relative response to a tax on nitrogen was independent of farm type. The change in pesticide treatment was calculated from the change in land use resulting from the models.

In the second method, nature values are targeted directly through general requirements from society to every farmer, and bonus-points to farmers who in addition have special opportunities - based on location and history of the farm - to maintain biotope qualities. Outline requirements on the quantity of natural areas and an evaluation of biotope quality are based on the literature and results presented in the preceding chapters.

7.2 Results and discussion

7.2.1 Tax on nitrogen

Concerning the land use variables presented in the preceding chapters (cf. Table 11), the percentage changes in spring barley and permanent grassland (= area outside rotation) in response to a tax on nitrogen would be small or even negative (Table 16). Thus the 1.7%

increase in the area of permanent grass in scenario 2 means that the increase in ha per farm ranges from 0.02 ha (Part-Time) to 0.12 ha (Large Cattle), and in scenario 1 permanent grass decreases by 2.9% because it is converted to rotational land. Concerning livestock, only scenario 2 results in a change (Table 16). The grazing potential - represented by the stock of cattle - decreases. However, the stock of pigs, which affects nature values negatively with manure and ammonium, also decreases. Scenario 2 involves the largest reduction in use of fertilizers and thereby the largest decrease in leaching of nitrogen (Table 16). The reductions are largest on clay. The over all reduction in the use of nitrogen fertilizer is largest concerning artificial fertilizer. Some of the reduction in use of fertilizer is compensated for by a 3-4% increase in pulses (Schou & Skop 1997). The over all reduction in fertilizer use was 30-40% (Schou & Skop 1997), and the reduction in cereal yield was 3-4% (Jensen 1997). Among farm types the reduction in use of artificial fertilizers and in leaching of nitrogen was largest for Large Pig farms.

Economic regulation by taxes and quotas on fertilizers and pesticides may have positive effects on nature values, but only to a minor degree. Thus the variables Area and Grazing, which are important from a nature point of view, are not expected to be affected by taxes and quotas in a way that significantly changes nature values. Indeed grazing potential decreases in response to a tax on nitrogen. Taxes on nitrogen do affect the use of artificial fertilizers, and the use of pesticides are only affected to a minor degree (Table 16). The application of less fertilizer could have a positive effect on nature values both through growing more undersown legumes to replace artificial nitrogen (as expected from the calculated increase in pulses) and through a reduction in crop yield. However, the reduction in yield to a level which allows enough space for wild plants in the field is 15% (cf. Chapter 4), corresponding to halving the amount of fertilizer applied in cereals (Paaby et al. 1993), and it cannot be obtained through realistic economic regulation by taxes and quotas. With a 100% per-unit tax on nitrogen, the reduction in yield was only 3-4%. A model including a tax on pesticides as well may have resulted in an even larger reduction of the pesticide treatment. However, the effect of a reduction in the application of pesticides on nature values depends on the effectiveness of the application, which is expected to increase further in response to economic regulations.

From a nature value point of view, a tax on nitrogen reducing leaching of nitrogen by 20-30% might be beneficial[1] to wet and aquatic biotopes such as spring mires, brooks, rivers, ponds and lakes that are fed by run off and infiltrated water from fields. Furthermore, the reduction in ammonia deposition as a consequence of the calculated reduction in the stock of pigs might be beneficial[8] to local oligotrophic/mesotrophic natural areas such as heath and commons. These effects are most pronounced in areas with large pig production farms. Apart from the mentioned impacts, beneficial effects on nature values from taxes on nitrogen and pesticides are small or even negative. Therefore, other measurements are needed.

[1] Possible beneficial effects have not been quantified.

Table 16 Changes (percentage or index) in land use (spring barley and permanent grass), livestock, pesticide treatment frequency, amount of fertilizer use, and leaching of nitrogen as a result of a per-unit tax on nitrogen. While scenario 1 includes a per-unit tax on artificial nitrogen fertilizer, only, scenario 2 also includes a tax on nitrogen in feed-stuff. Changes at the farm type level are given for scenario 2 on clay only, as the changes are greatest with this combination. Source: Data from Schou & Skop (1997) .

Scenario	Scenario 2							Scenario 1		Scenario 2	
Farm type	Part-Time PT	Small Cattle CS	Large Cattle CL	Small Plant PlS	Small Pig PS	Large Plant PlL	Large Pig PL	All farm types		All farm types	
Rank order of nature values (Cf. Table 11)	a	b	c	d	e	f	g				
Soil type	Clay							Sand	Clay	Sand	Clay
Changes											
AREA %											
Area with spring barley				1.9					0.4		1.9
Area with permanent grass				1.7					- 2.9		1.7
LIVESTOCK (Grazing potential) %											
Livestock, cattle				- 7.8					0		- 7.8
Livestock, pig				- 20.4					1.2		- 20.4
PESTICIDE TREATMENT %											
Total	-2	-3	-2	-2	-2	-2	2	-0.7	-0.9	-2.1	-2.1
FERTILIZER Index											
Manure	84	91	92	84	81	84	95	100	100	92	90
Artificial	46	47	50	53	17	53	6	51	48	53	43
Leaching	70	79	80	73	67	73	65	80	78	76	72

7.2.2 Requirements for nature values

In the second method the nature values are maintained through requirements for land use, management, and location, i.e. all landowners have an obligation to take nature values into consideration at a defined minimum standard, resulting in a certain minimum level of nature values at the farm level (here called baseline nature values). This for example could be implemented by changing the 1992 Protection of Nature Act from a law of dispensation into a law of requirement and/or proclamations of requirements. This has been done concerning the aquatic environment. The requirements for farming practice to protect nature values should thus be viewed at as equivalent to different requirements of farming practice taken to protect the ground water and the aquatic environment in general, such as 'winter green fields'[2], number of Livestock Units allowed per area, capacity of manure silos, weather and plant cover conditions for applications of manure etc. Also, certification of farms, including claim of baseline nature values could be used. Farmers could also receive rewards for bonus points given for increasing their natural areas and for having maintained high quality natural areas. However, the intention of this report is not to analyse socio-economical methods, but to outline different restrictions to and opportunities for farming practice that

[2] In Denmark the farmers according to the Aquatic Environmental Plan are required to have a 65% share of the so-called 'winter green fields' which are crop types that are expected to reduce the leaching of nitrogen from the root zone during winter, for example winter cereals, grass fields, catch crops, beets etc

should be included in an action plan if the protection of nature values (biodiversity), and the fulfilment of the Rio (biodiversity) Convention are targeted.

The *a priori* requirements at the farm level necessary to achieve a potential minimum standard of baseline nature values in relation to sustainable agriculture are outlined in Box 4.

The requirements outlined in Box 4 should secure a less intensive plant production of fields in rotation. Furthermore, more extensive, but proper grazing pressure both on fields within rotation and especially on fields outside rotation should result. The requirements for a baseline nature values also support other aspects of sustainable agriculture. For example, from a water quality point of view, the extensively managed grasslands outside rotation should be included as a special land use in relation to the requirement for 'winter green fields' and given maximum weight, if different land use areas are not weighted equal in calculating the proportion of 'winter green fields'. The requirement for the number of Livestock Units allowed on a farm in relation to the area available for manure should be based on the area within rotation only, and should be calculated from fertilizer needs of crops which are suitable for fertilization with manure. Requirements for a certain minimum number of days of outdoor grazing by cattle, as assumed in the calculation of grazing potential, is in accordance with animal welfare and should be integrated to sustainable agriculture.

The requirements outlined in Box 4 should also have a positive direct effect on nature values of biotopes such as spring mires, brooks, rivers, ponds and lakes that are fed by run off and infiltrated water from fields and on oligotrophic/mesotrophic types of natural areas such as heath and commons. Furthermore, a requirement for more grassland outside rotation is designed to increase the area of grasslands along rivers, which should be beneficial to aquatic biotopes - especially in areas with drained clay soil and dominated by plant and pig production (Skop & Loaiciga Submitted)

It is emphasised that quality of biotope may vary between different localities within a biotope type, and that restoring high quality biotopes with biotope characteristic plant communities is impossible within a reasonable time scale (cf. for example Schiefer 1984; Blab et al. 1995; Hald 1995; Mogensen et al. 1997a). Thus, regeneration is not possible within centuries for some biotope types, and for others the time is more than 150 years (Blab et al. 1995). If a former natural area has been managed intensively or cultivated, the prospects for restoration are even worse (cf. for example Kirkham & Kent 1997; Pywell et al. 1997). Even regeneration of a weed community characteristic of spring cereals takes a long time (Bischoff 1996). Therefore, existing natural areas of stable and long management tradition and of high quality should be a farmer's best treasure.

Restoring areas formerly of high nature value, i.e. natural areas with biotope characteristic plant communities, is impossible. Therefore, to protect existing natural areas, sustainable agriculture should not only be concerned with baseline nature values, but also include a quality dimension. In a sustainable agricultural system the nature values could thus be a combination of absolute requirements on all farms for defined baseline nature values as outlined in Box 4, and management of existing especially valuable natural areas resulting in a points system on which financial rewards can be paid. Farmers choosing among a number of measures and management alternatives of different weights.

Box 4
The *a priori* requirements for baseline nature values at farm level.

AREA
* Structurally, farmland should be as if the landscape was composed of 18 ha Part-Time farms with no greater than 9 ha fields separated physically by uncultivated areas of no less than 4 m in width. This comprises about 3% of the agriculturally managed area (in accordance with Statistics Denmark) occupied by linear small biotope.
* The total area occupied by area small biotope (< 2 ha) should be no less than 3.5% of the agriculturally managed area.
* The area of grassland outside rotation should be as if farmland was composed of cattle farms with no less than 13% of the agriculturally managed area as grassland outside rotation.

GRAZING
* The number of grazing equivalents per ha of areas outside rotation and within rotation should not differ from 2 and 6, respectively.

PESTICIDES & FERTILIZERS
* Reduced use of pesticides in general. In addition, a reduction should be effected through requirements for zero pesticide application on areas outside rotation, including small biotopes, and requirements for unsprayed rotational areas (for example in total 15% of areas in rotation) distributed at crop margins (9%) and as entire spring cereal fields (6%).
* Reduction in application of fertilizers in general - on cattle farms too. In addition, a reduction should be effected by specific requirements for no fertilizer application on areas outside rotation, including small biotopes, requirements for screening when fertilizer is applied along these areas and requirements for an effective application distance of 3 m to these areas when manure is applied.
* Requirements for current laws to be upheld. For example a 2 m uncultivated strip around ancient monuments and along rivers; one 'vejalen' (= 63 cm; varies in practice from 50 cm to 100 cm) of the horizontal part of road verges along all roads owned by the public; protection of all biotopes protected by §3 and §4 in the 1992 Protection of Nature Act.

LOCATION
* Farms types producing a high load of ammonia should not be located or have such a size that they affect local §3 natural areas or areas of potential oligotrophic/mesotrophic types of natural areas.

Some different measures and management alternatives giving farmers the opportunity to pay special attention to nature values in fields within rotation, in grasslands outside rotation, and in small biotopes are outlined in Box 5.

Box 5.
Measures and management which are subjected to farmers' choice and in addition to the baseline nature values.

Fields within rotation
* Spring sown cereals in combination with stubble fields during winter
* Allowance for more dicotyledonous weeds and insects in spring cereals through reduction in fertilizer to half the normal dose and no herbicides against dicotyledonous species and no insecticide.
* Undersown vegetation of cultivated dicotyledonous species in cereals, for example legumes.
* Grassland in rotation sown with legume species.
*[3] High biotop quality, for example six wild plant species per 0.1 m^2 (cf. Table 4)

Grasslands outside rotation
* Grazing of grassland or mowing combined with grazing.
* Converting grazing of grassland outside rotation to cutting twice a year.
* Converting grassland outside rotation which is too wet for grazing and mowing during summer to unmanaged areas.
*[4] High biotop quality, for example > one plant species per 10 m^2 characteristic of the plant community of an unimproved grassland (cf. Fig. 15, Table 6, Appendix 1 & Appendix 2).

Small biotopes
* Hedgerows of more than 4 m width to secure more space for a field layer rich in herb and grass species. This should be a standard requirement when a hedge is planted with economic subsidy.
* More than 6.6 % of the agriculturally managed area as small biotopes - with or without trees.
*[5] High biotop quality, for example more than five non-competitive wild plant species characteristic of unshaded open areas per 20 m of a linear biotope (cf. Table 7).

7.3 Discussion and conclusion

From a nature value point of view, the most interesting changes following a tax on nitrogen are less grazing potential, on the negative side, and on the positive side less leaching of nitrogen - especially from Large Pig farms - and a reduction in local ammonia deposition

[3] Preliminary suggestion. Has to be worked out in detail.
[4] Preliminary suggestion. Has to be worked out in detail.
[5] Preliminary suggestion. Has to be worked out in detail.

from pig farms following a reduction in the stock of pigs. In general, taxes or quotas on fertilizers and pesticides are not strong enough measures when nature values of terrestrial biotopes are targeted. Therefore, other measures are needed.

Measures targeting nature values directly are probably the only effective solution. In a sustainable agricultural system the nature values could thus be a combination of absolute requirements on all farms for a defined baseline nature values and management of existing especially valuable natural areas and, at the farmers choice, among a number of measures and management alternatives resulting in points of different weights.

The total nature values on a farm, i.e. baseline nature values plus quantitatively and qualitatively especially valuable natural areas, could be measured and regulated (economically) through summing up the weights and giving bonus points for special attention to nature values or for the existence of areas of high biotope quality, and penalty points if the baseline nature value requirement is not fully met. The resulting sum of points joins the basis for calculating the economic balance between the farmer and society.

8 Summary and conclusion

The interactions between agriculture and nature values in the agricultural landscape, i.e.values of semi-natural areas, small biotopes, and the vegetation in the rotational fields, are dualistic. Thus the occurrence in historical time of species rich semi-natural areas and the establishment of small biotopes ultimately resulted from farmer activity, and in the fields cultivation is necessary for the germination of the large number of annual plant species in the flora. Maintaining nature values was a by-product of former agriculture systems. However, the high productivity levels of contemporary agriculture do not *a priori* integrate the necessary extensive management of nature values. Therefore, maintaining the nature values of the agricultural landscape has to be taken into consideration as an integrated aspect of sustainable agriculture in the future. Also the indirect impact of agriculture on other types of natural areas through leaching and drift of nutrients has to be included in the concept of sustainable agriculture.

The agricultural structure of the study area - Vejle County - and land use are both found to be representative of the country as a whole. Only a small proportion (7 % of the total area) of the natural areas in Vejle County are protected by the 1992 Protection of Nature Act, similar to the country as a whole. The size of the protected natural areas is an always decreasing figure. About half the natural areas in the country are dependent on continuation of the grazing tradition, but abandonment followed by changes in the vegetation takes place more and more frequently. Once a grazing dependent natural area has been abandoned for a few years the literature documents that restoring the degraded nature values is difficult, and if the area has been improved agriculturally with fertilizer and cultivated grass species restoration is impossible within the time span of several human generations. Therefore, biotope quality - measured as the share of the biotope specific species within the vegetation - is also always decreasing. In contrast to grazing dependent types of natural areas, most of the small biotope types may be restored within the time of one to two generations.

Based on information in the literature this report describes observed changes in agriculture from the 1950's to the 1990's of variables that are expected to be important for nature values in the agricultural landscape (Chapters 2 and 3). The relationships between the variables of agriculture and the impact on nature values are referred from the literature (Chapter 4). As the total area occupied by different farm types is changing, the interactions between farm types and different types of natural areas is of interest. Also the effect of the present-day location of the various farm types on different types of natural areas is analysed (Chapter 5 and 6). Finally, the effect on nature values of a 100% per-unit tax on nitrogen is evaluated, and restrictions on farming practice which must be included in an 'Action Plan for Sustainable Agriculture' if nature values (biodiversity) are targeted and the aim is to fulfil the requirements of the Rio Convention on biodiversity are discussed (Chapter 7).

The changes in influencing variables during the period 1955-1995 that are expected to be important for nature values are great. The area of spring cereals decreased while the area of winter cereals increased, and the area with permanent grassland decreased to 57% from 1970[1] to 1995. Within the same period, the potential for grazing was reduced to 62%, while the number of pigs, a non-grazer, increased. However, the amount of manure produced has been constant. The yield of both plant production (cereals) and animal production (milk per cow) increased. While the total number of farms decreased, the size of farms increased, especially the number of farms in the largest size category (>100 ha) increased. Theoretically, only a small part of the landscape has not been involved in amalgamation during the period 1970 to 1995. As farms became larger, the general tendency was a change from cattle production to plant and pig production. Thus, farm type and the decisions taken by each farmer influence on larger and larger part of the agricultural landscape.

The intensification of agriculture has resulted in an increased yield from both plant and animal production, and the general trade-off between productivity and nature values of grasslands and fields in rotation has left its mark in the landscape. Grasslands outside rotation are improved to increase animal production or abandoned as high productivity diary cows mostly graze grass within rotation. Agricultural improvement of dry grasslands (commons) and meadows through application of fertilizers and sowing of cultivated grass species results in higher biodiversity. However, the number of habitat specific species decreases, and the improved area represents vegetation types with high nutrient levels and low light incidence, i.e. high productivity. Furthermore, the species in improved meadows represent drier vegetation types.

The higher yield of crops has impoverished the flora of fields in rotation. Mid field, the density of plants and species is about half that of crop margins. Growing winter cereals instead of spring cereals reduces the density of plants and species in the vegetation by about 25%. Finally, herbicide treatment reduces densities to less than two thirds of the level before spraying.

The existence of small biotopes becomes more precarious as farm size increases. They only occupy 3-4% of the agricultural landscape. Although small biotopes are in general highly affected by being next to fields in rotation, they provide refuge for perennial plant species in the agricultural landscape.

Farm types have been classified into Part-Time and Full-Time types. The Full-Time farms have been further classified according to line of production into Plant, Cattle, and Pig production farms and according to soil into farms on sand, clay, and mixed soil types. Finally, all Full-Time types have been divided into two size classes according to their economic turnover (standard gross margin). The influence of farm and soil type on five main variables has been analysed. The main variables were: area (area of the farm and land

[1] The period 1970 to 1995 is used for presentation of variables that vary with the area of Vejle County.

use); grazing potential (grazing within rotation by diary cows and outside rotation by other grazing animals); use of pesticides (herbicide, insecticide and fungicide) and nutrients (manure and artificial fertilizer); and location according to grazing dependent semi-natural areas, potential areas for permanent grasslands on low-lying land; and location of farms with high ammonia emission in relation to oligo-/mesotrophic areas sensitive to additional nutrient loads. In an amalgamated analysis of the influence on nature values of the different farm types, the main variables have been given equal weight.

The five main variables were influenced more by farm type than soil type. Among farm types, only grazing potential on grass within rotation and application of herbicide were not dependent on farm type. Within each economic size group, plant production farm type was largest (10 times the area of a Part-Time farm), and cattle farm type had the largest area with grassland outside rotation. Small cattle farms, however, had a higher percentage area outside rotation than large cattle farms. As the area of a farm is dependent on both the economic size and the line of production, the security of small biotopes varies. Large-Plant farms in particular are the largest potential threat to small biotopes. Plant and Pig farms have converted the largest area of spring cereals to winter cereals, and therefore have the lowest potential for wild flora in the fields. While Cattle farms have too many diary cows in relation to their area with grass within rotation, small Plant and Pig farms have too little grassland outside rotation in relation to the stock of grazing animals others than diary cows. The grazing dependent types of natural areas are located closest to Part-Time farms - on average within 500 m - while the distance to cattle farms is on average 1,000 m.

Assuming the area of a farm forms a circular area around the main farm building, the total area occupied by Part-Time farms contains more of all the types of natural areas except heath, than the area occupied by Small and Large Cattle farms together. These results are found irrespective of the fact that the total area occupied by Part-Time farms is less than the area occupied by the cattle farms. The difference between the area of grassland outside rotation and the potential for permanent grassland on low-lying land indicates that pig and plant production farms have the largest potential area of land for permanent grassland. In accordance with this, it is found that plant and pig productions farms do have a larger 'permanent' set-aside areas than the other farm types. It has been calculated that the zero-level of ammonia deposition from a Large Pig farm is at a distance larger than 600-1,000 m from the farm. Within a circular area with r=600 m around all Large Pig farms in Vejle County, there are 100 ha of dry oligo-/mesotrophic types of natural areas. Of the potential oligo-/mesotrophic types of natural areas, a higher percentage of the dry than of wet types occur within the impact sphere of Large Pig farms.

The amalgamated analysis of the influence on nature values of the different farm types shows that the different types potentially support or impact nature values to a different degree. The rank of farm types in relation to <u>expected nature values</u> is Part-Time > Small

Cattle > Large Cattle, Small Plant, Large Plant, Small Pig > Large Pig with Part-Time having the highest expected nature values and the highest potential to support nature values.

Calculation of the effect on nature values of a 100% per-unit tax on nitrogen in artificial fertilizers and feed-stuff shows that Large Pig farms demonstrate largest response. The stock of pigs and the use of artificial fertilizers and manure is reduced resulting in reduced leaching of nitrogen from the root zone. In general, the yield of cereals is reduced by 3-4%. From the point of view of nature values, a tax on nitrogen does reduce the level of negative impact, but the progress are too small. The positive effects are largest concerning oligo-/mesotrophic types of natural areas influenced by water leaving the root zone or from the emission of ammonia (spring-areas and heath, bogs and commons, respectively). A tax on nitrogen does not secure more natural areas or more space in the crop, nor does it secure continued grazing.

If nature values are to be targeted, indirect means such as tax on nitrogen do not greatly improve the nature values; direct measure are the only solution. A priori requirements at the farm level for a minimum of nature values (baseline nature values) are proposed. The requirements concern area, grazing, pesticides, fertilizers and location of farms. The requirements are that: baseline nature values are supported to the same degree by all farmers and should thus be independent of production line, farm size and soil type; the requirements do not need special geological or historical conditions. The best value of each main variable is proposed as the starting point for establishing the minimum requirements, i.e. the baseline nature values. In addition to fulfilling the requirements of baseline nature values, some farmers have special opportunities to maintain biotop qualities: either because the location and/or history of the farm offer special opportunities or because the farmer is especially interested in the nature values of the farm. It is suggested that these farmers be offered bonus-points.

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Appendix 1

Comparison of species abundance lists from ten localities of old unimproved and of improved dry grasslands respectively, both on clayey sand (Mols Bjerge) and each locality analysed by 10x0.1 m^2. Source: Ejrnæs & Bruun (1995a), Ejrnæs & Bruun (1995b), and pers. com. Maximum obtainable sum of scores (SSc) is 300 and species with SSc < 10 are not included. The species have been divided into five groups according to their biotope specificity and weediness. Species noted as weeds are species occurring with F% > 0.2 in rotational fields (x) and 2nd year grass leys in spring or summer analyses (g) (Data from Andreasen 1990).

Species		Sum of scores		Weeds
Only old dry grassland; SSc > 10; Non-weeds		**Old**	**Improved**	
Fåre-Svingel	Festuca ovina	179		
Hedelyng	Calluna vulgaris	55		
Liden Klokke	Campanula rotundifolia	54		
Lyng-Snerre	Galium saxatile	43		
Sand-Star	Carex arenaria	43		
Krat-Fladbælg	Lathyrus montanus	40		
Lund-Padderok	Equisetum pratense	30		
Nikkende Limurt	Silene nutans	30		
Pille-Star	Carex pilulifera	28		
Hvid Anemone	Anemone nemorosa	26		
Tormentil Potentil	Potentilla erecta	22		
Tandbælg	Sieglingia decumbens	19		
Hunde-Viol	Viola canina	16		
Opret Kobjælde	Pulsatilla vulgaris	16		
Eng-Havre	Helictotrichon pratense	15		
Alm. Kællingetand	Lotus corniculatus	14		
Håret Løvefod	Alchemilla vestita	14		
Alm. Mælkeurt	Polygala vulgaris	13		
Alm. Pimpinelle	Pimpinella saxifraga	13		
Flipkrave	Teesdalia nudicaulis	12		
Only old dry grassland; Weeds				
Glat vejbred	Plantago major	1		xg
Both on old and improved dry grassland; Five most important species from each type				
Alm. Hvene	Agrostis tenuis	184	103	
Håret Høgeurt	Hieracium pilosella	141	77	x
Bølget Bunke	Deschampsia flexuosa	127	2	x
Mark-Krageklo	Ononis repens	83	1	
Alm. Røllike	Achillea millefolium	81	116	xg
Eng-Rapgræs	Poa pratensis ssp.pratensis	69	156	
Rød Svingel	Festuca rubra	80	126	
Alm. Rajgræs	Lolium perenne	3	118	x
Lancet-Vejbred	Plantago lanceolata	67	116	x
Only improved dry grassland; SSc > 10; Non-weeds				
Femhannet Hønsetarm	Cerastium semidecandrum		98	
Alm. Hundegræs	Dactylis glomerata		84	
Blød Hejre	Bromus hordeaceus ssp.hordeaceus		66	
Gul Kløver	Trifolium campestre		61	
Stribet Kløver	Trifolium striatum		49	
Mark-Frytle	Luzula campestris		36	

Species		Sum of scores		Weeds
Only improved dry grassland; SSc > 10; Non-weeds		**Old**	**Improved**	
Hare-Kløver	Trifolium arvense		24	
Ager-Snerle	Convolvulus arvensis		22	
Eng-Gedeskæg	Tragopogon pratensis ssp.pratensis		17	
Vår-Gæslingeblomst	Erophila verna		17	
Eng-Brandbæger	Senecio jacobaea		16	
Mark-Bynke	Artemisia campestris		15	
Muse-Vikke	Vicia cracca		10	
Nælde-Klokke	Campanula trachelium		10	
Only improved dry grassland; SSc > 10; Weeds				
Mark-Ærenpris	Veronica arvensis		77	x
Alm. Kvik	Elytrigia repens		74	x
Alm. Dværgløvefod	Aphanes arvensis		39	xg
Tofrøet Vikke	Vicia hirsuta		29	x
Blød Storkenæb	Geranium molle		27	xg
Alm. Rapgræs	Poa trivialis		27	x
Ager-Padderok	Equisetum arvense		26	x
Rød-Kløver	Trifolium pratense		21	x
Enårig Rapgræs	Poa annua		21	xg
Lav Ranunkel	Ranunculus repens		19	xg
Hvid-Kløver	Trifolium repens		17	x
Alm. Fuglegræs	Stellaria media		14	xg
Kløftet Storkenæb	Geranium dissectum		12	x

Appendix 2

Comparison of species occurrence in three types of mesotrophic meadows found by TWINSPAN from a national survey (Mark 1997): 1) Wet, 2) Moist, i.e. slightly drained and fertilised, 3) Moist and further improved meadow. The species list from each of the three types of meadow are drawn from 10 samples each of 1m^2 and from different localities. Maximum sum of scores per species is 90 (Van der Maarel abundance scale 1-9). Species that occurred in one type only, and with sum of scores < 4 are excluded. Source: Mark (1997). TWINSPAN analysis by Bettina Mogensen.

Meadow type		Wet	Moist	Moist Improved
Number of species per 1m^2		6.7	9.7	10.3
Total number of species		34	43	53
Species occurring in all three types of meadows (17 species)			Sum of scores	
Krybhvene	Agrostis stolonifera	55	11	5
Gåsepotentil	Potentilla anserina	29	8	21
Lav Ranunkel	Ranunculus repens	24	33	22
Mose-Bunke	Deschampsia caespitosa	22	36	6
Alm. Rapgræs	Poa trivialis	15	36	14
Fløjlsgræs	Holcus lanatus	7	23	6
Alm. Syre	Rumex acetosa	7	8	8
Lyse-Siv	Juncus effusus	6	23	10
Hvid Kløver	Trifolium repens	6	9	15
Eng-Rapgræs	Poa pratensis	4	11	7
Mælkebøtte	Taraxacum sp.	3	14	12
Alm. Hønsetarm	Cerastium fontanum	3	14	10
Kær-Snerre	Galium palustre ssp. palustre	3	5	9
Kær-Tidsel	Cirsium palustre	3	2	7
Dynd-Padderok	Equisetum fluviatile	2	7	8
Eng-Svingel	Festuca pratensis	2	5	12
Sværtevæld	Lycopus europaeus	2	3	1
Species occurring on wet meadows, only (7 species)				
Blære-Star	Carex vesicaria	8	0	0
Tykbladet Ærenpris	Veronica beccabunga	4	0	0
Kær-Trehage	Triglochin palustre	4	0	0
Kantet Dueurt	Epilobium tetragonum	4	0	0
Species occurring in two of the three types of meadows (19 species)				
Knæbøjet Rævehale	Alopecurus geniculatus	29	19	0
Kruset Skræppe	Rumex crispus	4	9	0
Vand-Mynte	Mentha aquatica	4	8	0
Sump-Fladstjerne	Stellaria alsine	4	4	0
Kær-Guldkarse	Rorippa palustris	2	4	0
Toradet Star	Carex disticha	7	0	9
Håret Star	Carex hirta	3	0	6
Liden Skjaller	Rhinanthus minor	2	0	5
Rød Kløver	Trifolium pratense	3	0	4
Ager-Tidsel	Cirsium arvense	5	0	1
Alm. Rajgræs	Lolium perenne	0	10	17
Rød Svingel	Festuca rubra	0	9	13
Eng-Rævehale	Alopecurus pratensis	0	9	1
Alm. Hvene	Agrostis tenuis	0	8	8
Rørgræs	Phalaris arundinacea	0	7	9
Vand-Pileurt	Polygonum amphibia	0	5	5
Alm. Hundegræs	Dactylis glomerata ssp. glomerata	0	4	6
Kær-Ranunkel	Ranunculus flammula	0	4	3
Tagrør	Phragmites australis	0	3	7

Meadow type		Wet	Moist	Moist Improved
Number of species per $1m^2$		6.7	9.7	10.3
Total number of species		34	43	53
Species occurring on slightly drained meadows, only (12 species)				
Stiv Star	Carex elata	0	7	0
Fuglegræs	Stellaria media	0	6	0
Krybende Hestegræs	Holcus mollis	0	5	0
Blågrøn Star	Carex flacca	0	5	0
Alm. Skjolddrager	Scutellaria galericula	0	4	0
Vild Kørvel	Anthriscus sylvestris	0	4	0
Species occurring on slightly improved grasslands, only (22 species)				
Bidende Ranunkel	Ranunculus acris	0	0	12
Hirse-Star	Carex panicea	0	0	8
Alm. Star	Carex nigra	0	0	7
Opret Potentil	Potentilla erecta	0	0	6
Eng-Kabbeleje	Caltha palustris	0	0	6
Mangeblomstret Frytle	Luzula multiflora ssp. multiflora.	0	0	5
Hvid Snerre	Galium album	0	0	5
Alm. Kamgræs	Cynosurus cristatus	0	0	5
Alm. Røllike	Achillea millefolium	0	0	5
Eng-Rottehale	Phleum pratense	0	0	4
Hjortetrøst	Eupatorium cannabinum	0	0	4
Lådden Dueurt	Epilobium hirsutum	0	0	4
Bølget Bunke	Deschampsia flexuosa	0	0	4
Skvalderkål	Aegopodium podagraria	0	0	4

Appendix 3

Developments in the field of landscape ecology have created a need for new terminology, or at least, more precise definition of terms used. The use of the word 'habitat' in the English language is considered rather too general for this report, since the 'habitat' of animals often includes more than one biotope, whereas the habitat of plants includes only one biotope. As this report mostly concerns the relationships between agriculture and the vegetation, the term 'biotope' is used and is defined below. Certain other terms have now become established in the Danish language and an explanation and definition of their translation to English and usage is given below.

BIOTOPE
Biotop (Danish (D)). The definition of 'biotope' as used in this report is a physical item, as for example a field, a hedge and a meadow. Different biotopes within the same category may consist of one to several vegetation types.

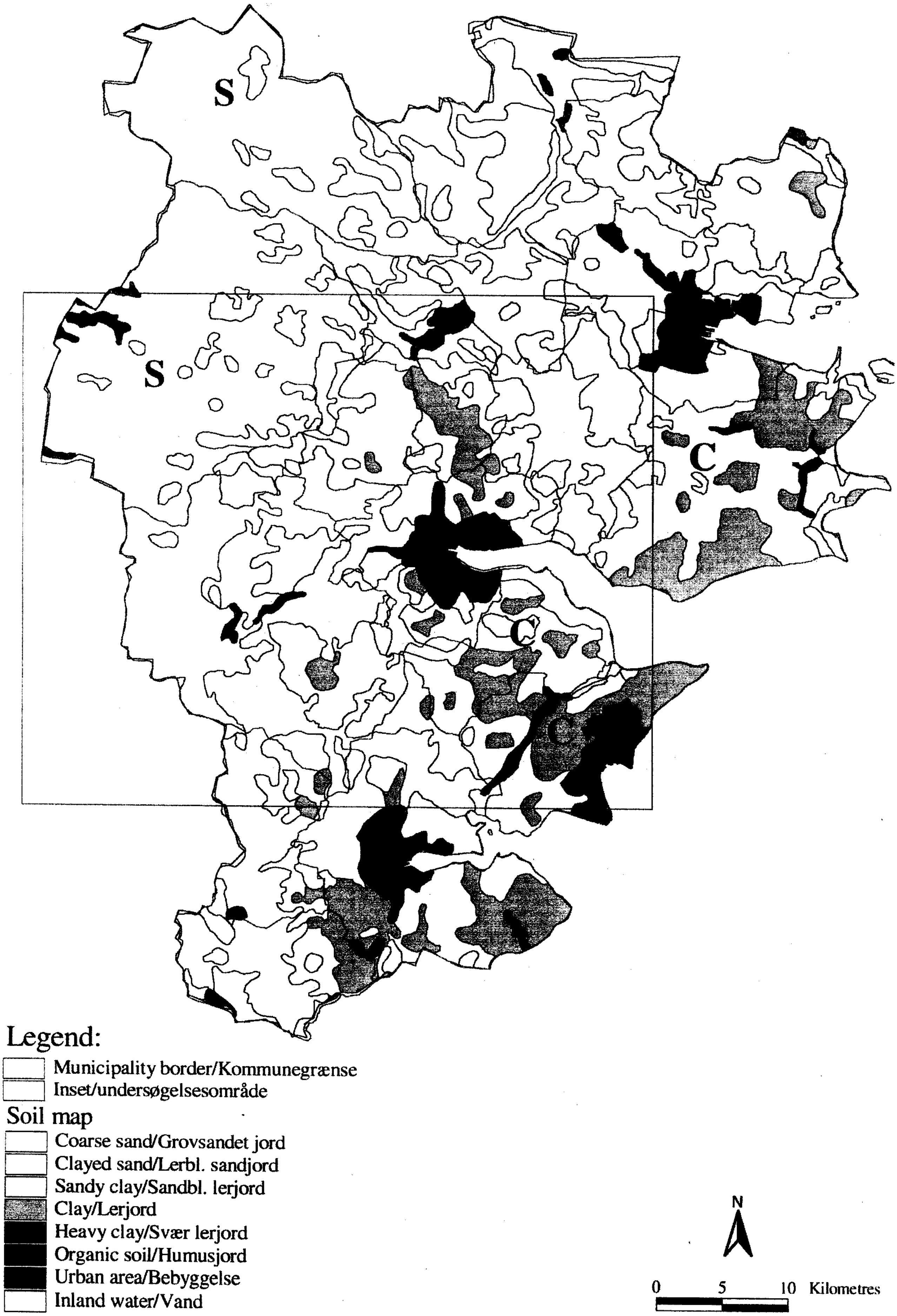
SMALL BIOTOPE
Små biotop (D). The term 'small biotope' is used in accordance with Agger & Brandt (1988) and Brandt et al. (1994). Small biotopes consist of physical features in the landscape that are either linear, such as a hedge, ditch, bank, wall etc., or areas of < 2 ha that are clearly distinguished from their surroundings, such as marl pit, woodlot or grave mound (Biotopgruppen 1986).

TYPE OF NATURAL AREA / BIOTOPE TYPE / VEGETATION TYPE
Natur type (D) ~ type of natural area / vegetation type (English (E)). The three terms: natural area, biotope type and vegetation type, used in this report refer to different things. In Denmark, only very small natural areas, i.e. areas not been created or altered by man, remain. These include for example bogs, dunes, slopes and reeds. In this report, therefore, the term 'natural areas' is used in a broad sense and includes various types of semi-natural areas as well as small biotopes, i.e. areas outside rotation, while the terms biotope and vegetation types also include wild flora (weed) and fauna in fields in rotation. A biotope type is often comprised of several vegetations types.'Vegetation type' is the most narrowly defined term: the vegetation type of a biotope type differs in response to management and other human impacts.

BIOTOPE QUALITY
Natur kvalitet (D). The term 'biotope quality' is largely defined and quantified through the presence or absence of different plant species in the vegetation. This report presents the results of a botanical investigation, for which the above definition is sufficient. However, the Danish term "natur kvalitet" can also be used to describe the quality of a habitat for fauna, and would then include not only the botanical quality of the relevant biotopes, but also the structure of the vegetation and the spatial arrangement of the biotopes as well.

NATURE VALUE
Natur værdi (D). The term 'nature value' is used as a general, unquantified description of biotope quality, and include the values of semi-natural areas, small biotopes as well as the wild plants (weeds) and fauna in fields in rotation.

LOADS ON NATURAL VALUES (FLORA AND FAUNA) OF PESTICIDES AND FERTILIZERS
Belastning af naturen med pesticider og gødning (D). This term refers to an unquantified impact on natural areas (the flora and fauna) of pesticides and fertilizers. Pesticide load is measured as the use of pesticides on fields in rotation, either as treatment frequency or as kg active ingredients per ha of agricultural area. The impact on the wild flora and fauna is seldom quantified, and affects both flora and fauna within as well as outside the targeted field.


S
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Legend:
Municipality border/Kommunegrænse
Inset/undersøgelsesområde
Soil map
Coarse sand/Grovsandet jord
Clayed sand/Lerbl. sandjord
Sandy clay/Sandbl. lerjord
Clay/Lerjord
Heavy clay/Svær lerjord
Organic soil/Humusjord
Urban area/Bebyggelse
Inland water/Vand
N
0 5 10 Kilometres

Figure 1

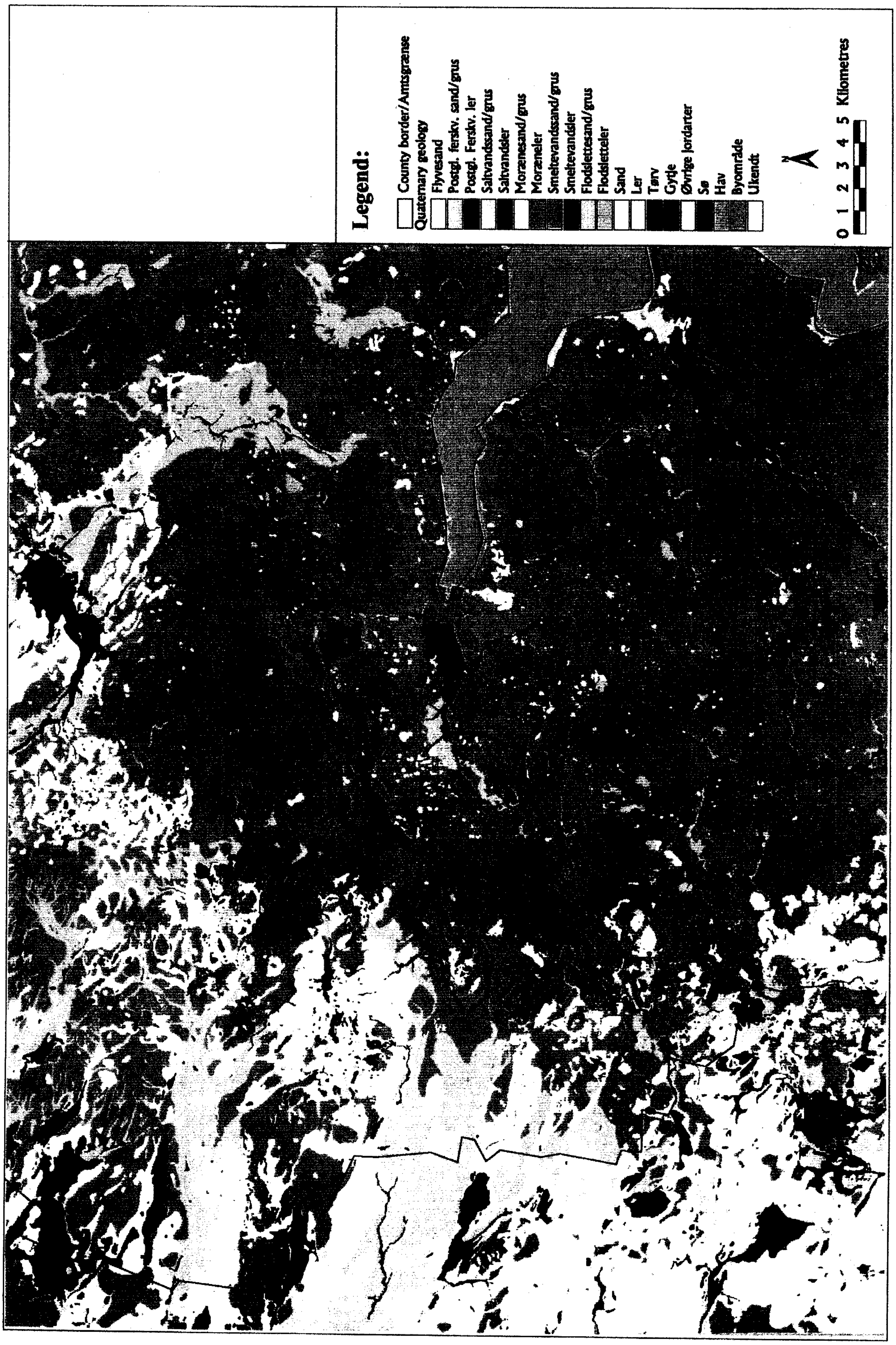
Legend:
County border/Amtsgrænse
Quaternary geology
Flyvesand
Postgl. ferskv. sand/grus
Postgl. Ferskv. ler
Saltvandssand/grus
Saltvandsler
Morænesand/grus
Moræneler
Smeltevandssand/grus
Smeltevandsler
Flodslettesand/grus
Flodsletteler
Sand
Ler
Tørv
Gytje
Øvrige jordarter
Sø
Hav
Byområde
Ukendt
N
0 1 2 3 4 5 Kilometres

Figure 2

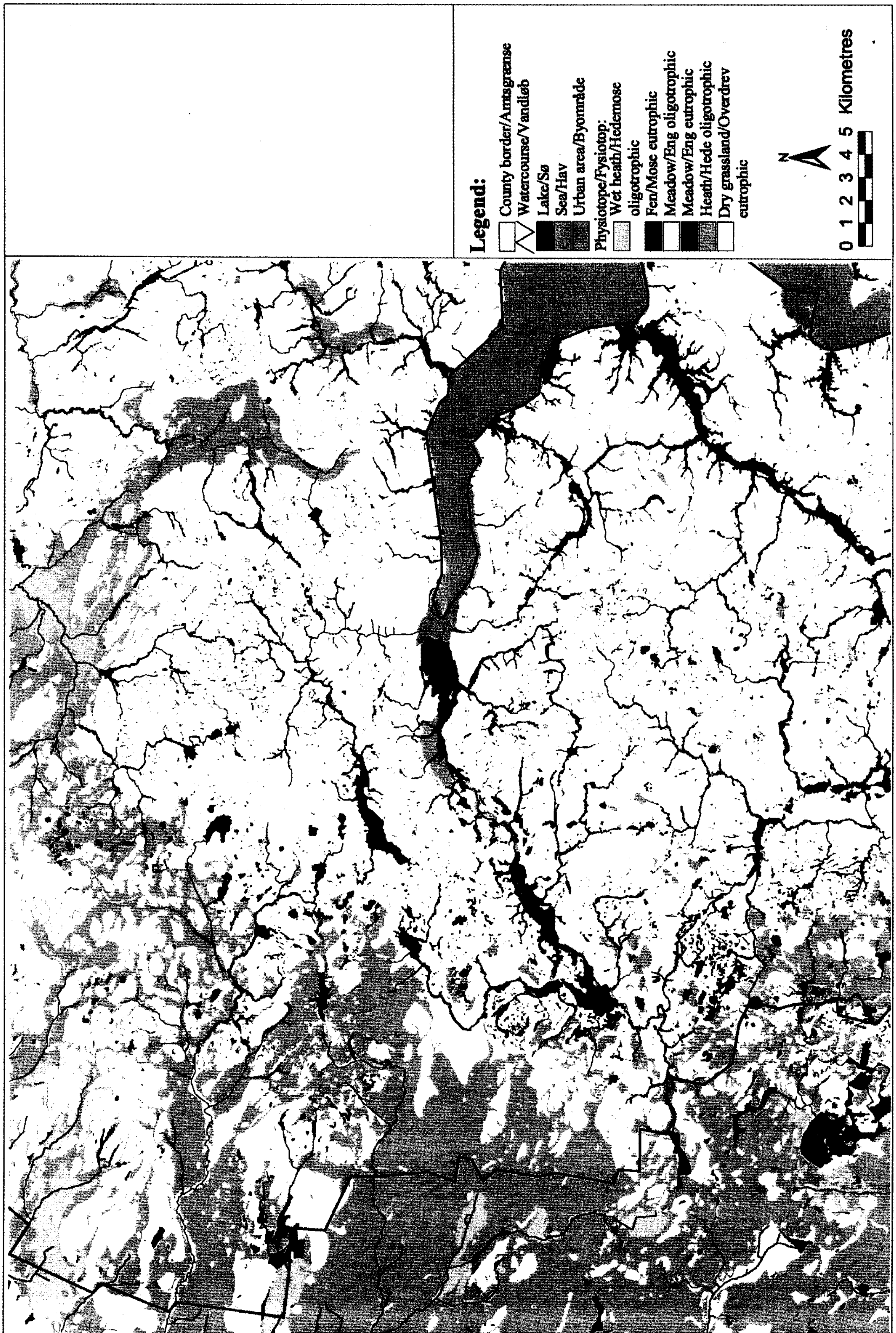
Legend:
County border/Amtsgrænse
Watercourse/Vandløb
Lake/Sø
Sea/Hav
Urban area/Byområde
Physiotope/Fysiotop:
Wet heath/Hedemose
oligotrophic
Fen/Mose eutrophic
Meadow/Eng oligotrophic
Meadow/Eng eutrophic
Heath/Hede oligotrophic
Dry grassland/Overdrev
eutrophic
N
0 1 2 3 4 5 Kilometres

Figure 3

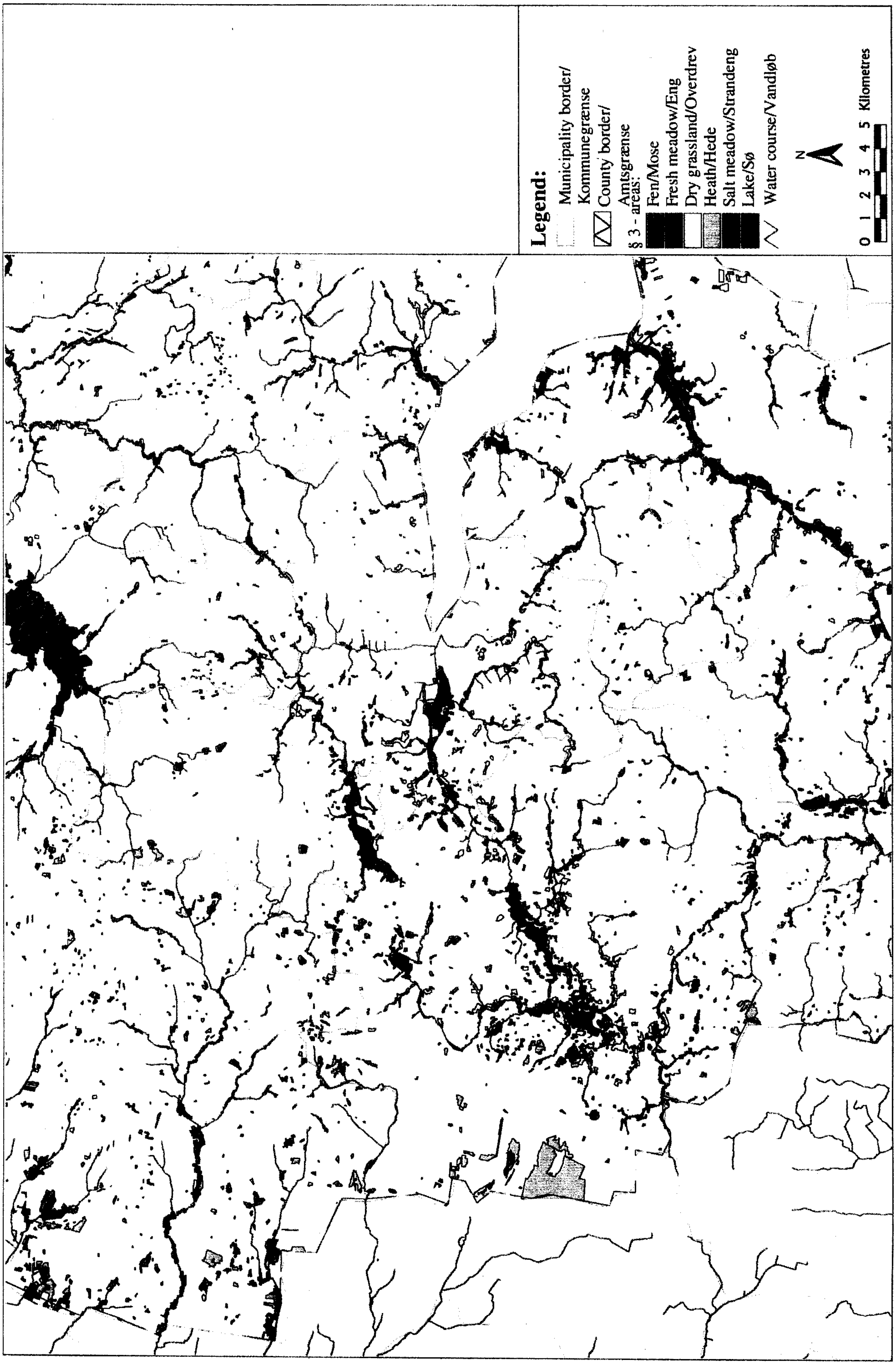
Legend:
Municipality border/
Kommunegrænse
County border/
Amtsgrænse
§ 3 - areas:
Fen/Mose
Fresh meadow/Eng
Dry grassland/Overdrev
Heath/Hede
Salt meadow/Strandeng
Lake/Sø
Water course/Vandløb
N
0 1 2 3 4 5 Kilometres

Figure 5

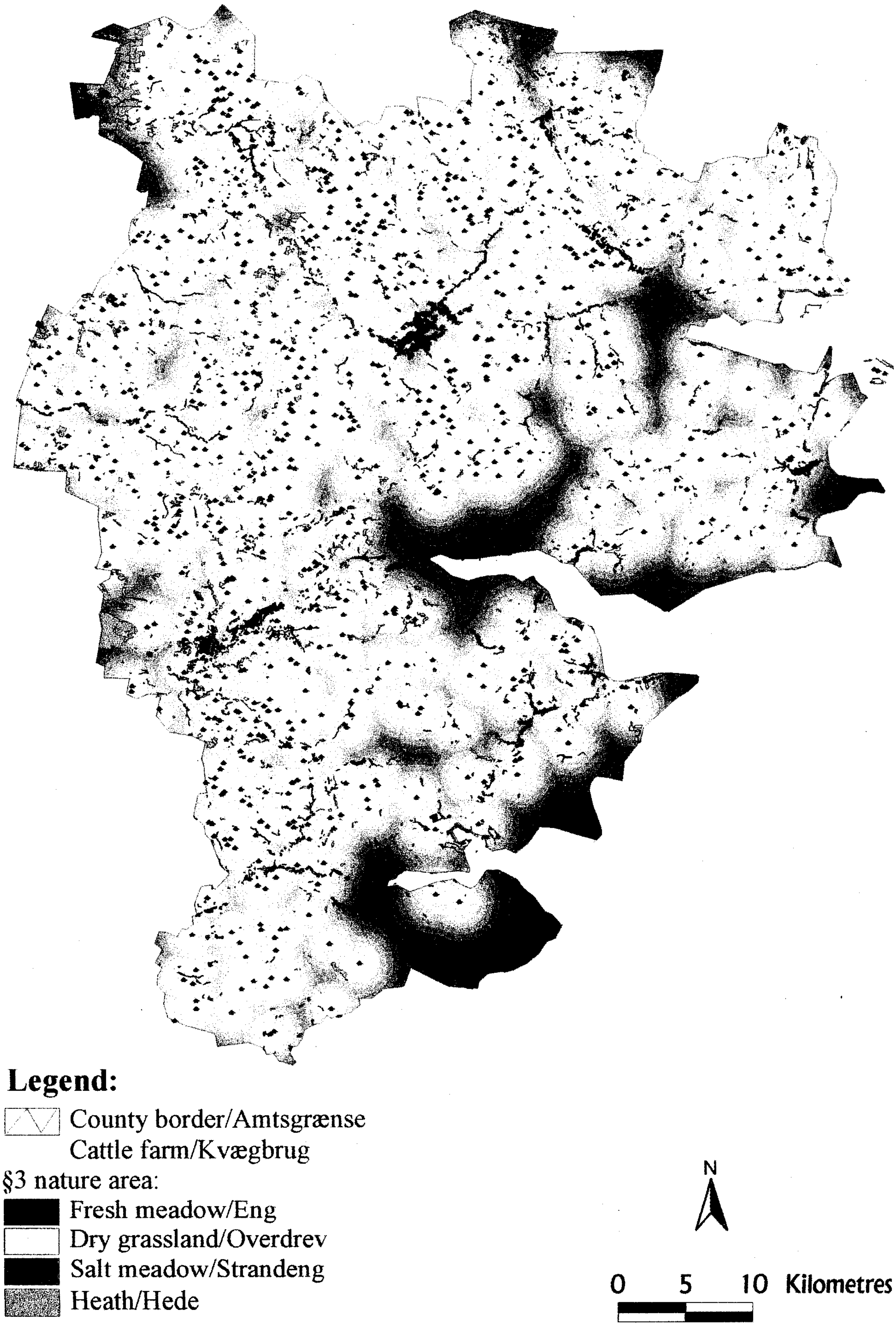
Legend:
County border/Amtsgrænse
Cattle farm/Kvægbrug
§3 nature area:
Fresh meadow/Eng
Dry grassland/Overdrev
Salt meadow/Strandeng
Heath/Hede
N
0 5 10 Kilometres

Figure 22

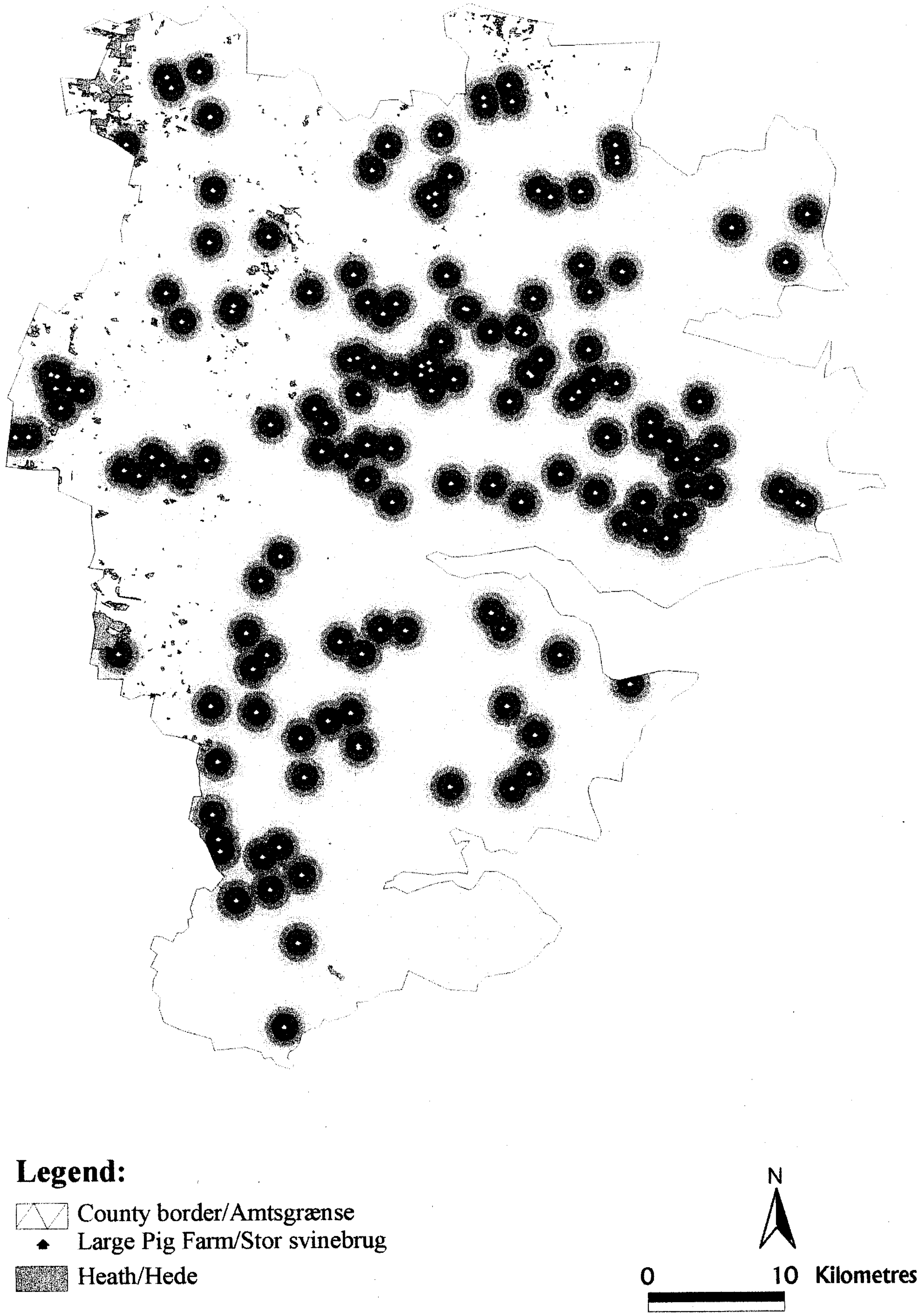
Legend:
County border/Amtsgrænse
Large Pig Farm/Stor svinebrug
Heath/Hede
N
0
10 Kilometres

Figure 23

National Environmental Research Institute

The National Environmental Research Institute, NERI, is a research institute of the Ministry of Environment and Energy. In Danish, NERI is called *Danmarks Miljøundersøgelser (DMU).*
NERI's tasks are primarily to conduct research, collect data, and give advice on problems related to the environment and nature.

Addresses:

URL: http://www.dmu.dk

National Environmental Research Institute
Frederiksborgvej 399
PO Box 358
DK-4000 Roskilde
Denmark
Tel: +45 46 30 12 00
Fax: +45 46 30 11 14

Management
Personnel and Economy Secretariat
Research and Development Section
Department of Atmospheric Environment
Department of Environmental Chemistry
Department of Policy Analysis
Department of Marine Ecology and Microbiology

National Environmental Research Institute
Vejlsøvej 25
PO Box 413
DK-8600 Silkeborg
Denmark
Tel: +45 89 20 14 00
Fax: +45 89 20 14 14

Department of Lake and Estuarine Ecology
Department of Terrestrial Ecology
Department of Streams and Riparian areas

National Environmental Research Institute
Grenåvej 12, Kalø
DK-8410 Rønde
Denmark
Tel: +45 89 20 17 00
Fax: +45 89 20 15 14

Department of Landscape Ecology
Department of Coastal Zone Ecology

National Environmental Research Institute
Tagensvej 135, 4
DK-2200 København N
Denmark
Tel: +45 35 82 14 15
Fax: +45 35 82 14 20

Department of Arctic Environment

Publications:
NERI publishes professional reports, technical instructions, and the annual report. A R&D projects' catalogue is available in an electronic version on the World Wide Web.
Included in the annual report is a list of the publications from the current year.

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